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2-580

TECHNICAL REPORT NO. 2-580

SAVANNAH HARBOR INVESTIGATION AND MODEL STUDY

Volume III

RESULTS OF MODEL INVESTIGATIONS

Section 6

RESULTS OF TESTS OF BANK EROSION IN NORTH CHANNEL

by

H. B. Simmons

H. J. Rhodes

October 1965

Sponsored by

U. S. Army Engineer District
Savannah, Georgia

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

AD-624 932

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Foreword

The model investigation of Savannah Harbor was initiated by the U. S. Army Engineer Waterways Experiment Station (WES) in December 1954 at the request of the U. S. Army Engineer District, Savannah, CE. The model was designed and constructed during the period December 1954-August 1955, hydraulic adjustments were made from September 1955-May 1956, and the general investigation and testing program was accomplished during the period June 1956-December 1964.

The final report of the model investigations is issued in several sections. Section 1 describes the problem which necessitated the model investigations, the verification of the model, and general studies conducted thereon. Section 2 describes the tests of a series of proposed improvement plans, results obtained, and conclusions. Section 3 presents the results of model tests of refinements and modifications of previously tested schemes involving sediment basins and freshwater diversion plans for reduction of shoaling in the harbor. Section 4 presents the results of additional model tests of schemes selected as the best measures for reducing maintenance dredging costs for Savannah Harbor. These additional tests were necessitated by changes, requested by local interests, in project dimensions in the form of increases in depths and widths of the ship channel. Section 5 describes hydraulic, shoaling, and pollution tests of Wilmington River. This report (Section 6) describes results of model tests to determine the effects of recommended changes in project channel dimensions and construction of a proposed sediment trap in Back River on bank erosion in North Channel.

The tests reported herein were requested by the Savannah District in 3d Indorsement, dated 29 September 1964, to WES letter dated 24 July 1964, subject: "Savannah Harbor Model Studies," and were conducted during

October-December 1964. The tests were under the general supervision of Messrs. E. P. Fortson, Jr., Chief, Hydraulics Division; G. B. Fenwick, Assistant Chief, Hydraulics Division; and H. B. Simmons, Chief, Estuaries Branch; and under the immediate supervision of Mr. H. J. Rhodes, Jr., Project Engineer. This report was prepared by Messrs. Rhodes and Simmons.

Directors of the WES during the construction, testing, and report preparation phases of the study were Col. C. H. Dunn, CE; Col. A. P. Rollins, Jr., CE; Col. Edmund H. Lang, CE; Col. Alex G. Sutton, Jr., CE; and Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

Contents

Summary

Tests were conducted in the Savannah Harbor model to determine the effects on hydraulic conditions in North Channel, in the reach just upstream from Fields Cut, of construction of the recommended Savannah Harbor improvement plan (increase in width and depth of navigation channel, plus construction of the Back River sediment trap). Considerable bank erosion has occurred in this reach of North Channel since 1950, and information was needed as to whether hydraulic conditions leading to such erosion would be altered appreciably by construction of the recommended plan. The results of the model tests indicate that construction of the recommended plan will cause appreciable reductions in maximum current velocities in the critical reach, and it follows that the rate of bank erosion should also be reduced appreciably.

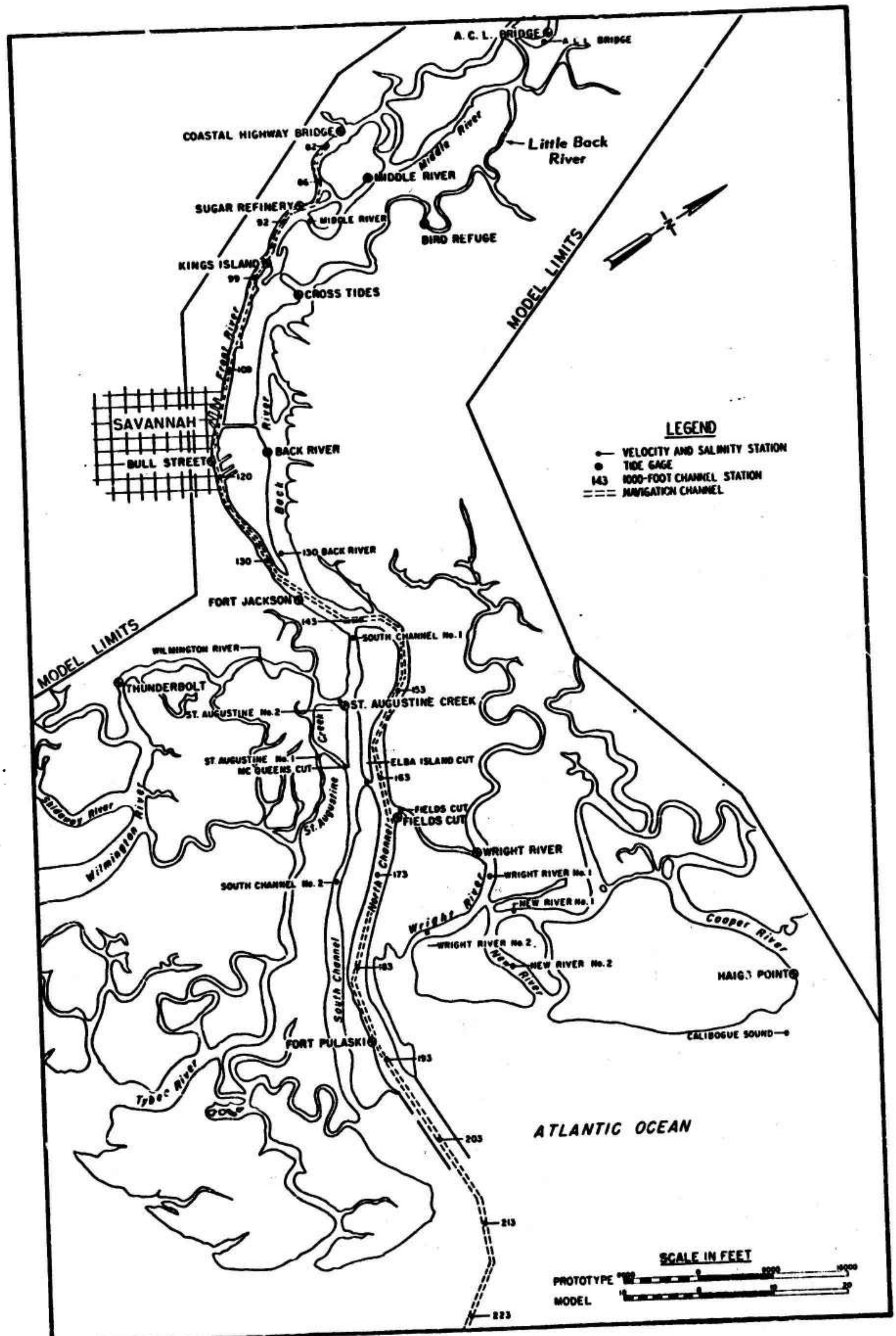


Fig. 1. Prototype area reproduced by model

SAVANNAH HARBOR INVESTIGATION AND MODEL STUDY

VOLUME III

RESULTS OF MODEL INVESTIGATIONS

SECTION 6. RESULTS OF TESTS OF BANK EROSION IN NORTH CHANNEL

Purpose of Tests

1. Considerable bank erosion has occurred since about 1950 in that reach of North Channel just upstream from Fields Cut, and especially along the right bank. If erosion should continue in that area, there is danger that undesirable navigating conditions, as well as serious shoaling, may develop in Elba Island Cut (fig. 1) of the Intracoastal Waterway. A plan for improvement of Savannah Harbor has been recommended, consisting of widening and deepening the navigation channel and construction of the Back River sediment trap. The tests reported herein were conducted to determine to what extent existing hydraulic conditions leading to bank erosion in North Channel would be changed by construction of the recommended improvement plan.

The Model

2. The Savannah Harbor model is of the fixed-bed type, constructed of concrete to linear scale ratios (model to prototype) of 1:800 horizontally and 1:80 vertically. Other significant scale ratios are given below.

Dimension	Ratio, Model to Prototype
Horizontal distance	1:800
Vertical distance	1:80
Area:	
Cross-sectional	1:64,000
Horizontal plane	1:640,000
Volume	1:51,200,000
Velocity	1:8.9443
Discharge	1:572,433
Time	1:89.443

The prototype area reproduced in the model is shown in fig. 1. Tides and tidal currents are reproduced in the model by means of a primary tide generator located in the model ocean area and a secondary tide generator, which is synchronized with the first and consists of a two-way flow-control device, located at the model limit in Calibogue Sound.

3. The hydraulic and salinity adjustments of the model, which are described in detail in Section 1 of this report,* assured an accurate reproduction throughout the model of (a) tidal elevations with respect to time, (b) the strength and duration of ebb and flood currents both in vertical and in plan, and (c) the distribution of salinity in both plan and vertical.

Test Conditions

4. In the Savannah Harbor model, tests were made of two channel conditions to determine the changes in current velocities and directions in the critical area that could be expected following recommended changes in project channel dimensions and construction of the proposed Back River sediment trap and tide gate. For the first of these conditions, the project channel was molded to the 1950 hydrographic survey (to which the entire model was constructed) except for the problem area of North Channel between sta 151 and 163 (plate 1) which was remolded to a 1964 channel survey to reflect the present eroded conditions of the right bank. For the second condition, the recommended Savannah Harbor improvement plan, consisting of a 38-ft-deep by 500-ft-wide project channel in combination with the Back River sediment trap and tide gate (Phase IX, scheme 4, test 8** of the Savannah Harbor model study), was installed in the model. However, in order to make use of the results of previous tests of the recommended plan, the 1950 bankline condition in North Channel was installed in the model for these tests, rather than the 1964 bankline condition.

* U. S. Army Engineer Waterways Experiment Station, CE, Savannah Harbor Investigation and Model Study; Volume III, Results of Model Investigations; Model Verification and Results of General Studies, Technical Report No. 2-580, Section 1 (Vicksburg, Mississippi, October 1961).

** Described in Section 4 of this report.

Tests and Results

5. In the model tests a mean tide and a freshwater discharge of 7000 cfs were reproduced. Test data consisted of current velocities measured at surface, middepth, and bottom at the 14 velocity stations shown in plate 1 and photographs showing current directions and velocities in the problem area. Test procedures and instruments used in these tests are described in detail in Section 1 of this report. The results of the model tests are presented in table 1, plates 2-19, and photographs 1-26.

6. Examination of plates 2-15, on which are plotted current velocities at all stations for both test conditions, shows that the recommended channel enlargement, including operation of the Back River sediment trap and tide gate, resulted in general reductions in current velocities throughout the problem area as compared with the 1964 conditions. The effects may also be noted from table 1 which presents a summary of maximum flood and ebb velocities at surface, middepth, and bottom for all stations for both channel conditions. Of particular interest are the effects on maximum ebb velocities at middepth and bottom on the right prism line at sta 159, 161, and 163, and on maximum flood velocities at middepth and bottom on the right prism line at sta 161 and 163, since it appears that these currents are likely to be responsible for much of the bank erosion noted in the problem area.

7. At sta 159R, the maximum ebb velocity at middepth was reduced by about 0.6 fps, while that at the bottom was reduced by about 0.7 fps. At sta 161R, the maximum ebb velocity at middepth was increased by about 0.6 fps but that at the bottom was reduced by about 0.6 fps; during flood at this station, the maximum velocity at middepth was increased by about 0.5 fps while that at the bottom was not changed. At sta 163R, the maximum ebb velocity at middepth was reduced by about 1.2 fps while that at the bottom was reduced by about the same amount; during flood at this station, the maximum velocity at middepth was not changed while that at the bottom was increased by about 0.3 fps. Thus, the reductions in velocities at these critical stations were substantial, while the few increases noted appear to be of little consequence.

8. Comparison of photographs 1-13, which show surface current directions and velocities for the 1964 channel conditions at hourly intervals throughout a complete tidal cycle, with photographs 14-26, which show similar information for the recommended channel enlargement, indicates that the enlarged channel would cause no significant changes in surface flow patterns and velocities. In these photographs, the velocity of the surface current in feet per second prototype in any area of the channel can be determined by measuring the length of a confetti streak in inches and multiplying by 2.64. This factor takes into consideration the scale of the photographs and the model-to-prototype scale relations for distance, time, and velocity.

9. Plates 16-19 show percent change of total flow at surface, middepth, and bottom for both ebb and flood flows and on both right and left prism lines. Total ebb and flood flows were computed by multiplying observed current velocities in feet per second by duration in hours. Data presented in plates 16-19 indicate that hydraulic forces available to erode the channel were reduced appreciably for conditions of the recommended plan.

Discussion of Results

10. In retrospect, it would probably have been more reasonable to incorporate the 1964 bankline condition of North Channel in both series of tests reported herein, so the difference in hydraulic conditions observed for the two channel conditions would have reflected directly the effects of construction of the recommended plan. However, for the reason stated in paragraph 4, the recommended plan was tested for the 1950 rather than the 1964 bankline condition. It is believed, therefore, that model indications of reductions in maximum velocities caused by the recommended plan are on the conservative side, since the total cross-sectional area of the channel in the problem area would have been greater if the 1964 bankline had been incorporated in the model for tests of the recommended plan.

11. From a theoretical viewpoint, the direct effects of bank erosion in North Channel on hydraulic conditions in the problem area could be

determined by comparing the results of tests of the existing channel reported herein, which incorporated the 1964 bankline, with the results of earlier base tests reported in previous sections of this report, all of which incorporated the existing channel and the 1950 bankline. However, for the following two reasons, such a comparison could lead to erroneous results. First, current velocities were observed at channel center-line stations only in the early base tests, so that comparisons of velocity changes in the critical areas near the banks of the channel are not possible. Second, while the early base tests were made for exactly the same combination of model operating conditions (tides, upland discharge, etc.) as were used for the tests reported herein, it is possible that small changes occurred in the exact placement of model roughness elements in the two or more years that elapsed between the tests, and such changes could lead to erroneous indications of changes in local current velocities.

12. The results of the two series of tests reported herein indicate that construction of the recommended plan of improvement for Savannah Harbor would cause appreciable reductions in maximum current velocities in the critical reach of North Channel. If the 1964 bankline had been incorporated in the model during tests of the recommended plan, it is probable that the indicated reductions in maximum velocities would have been even greater.

Recommendations

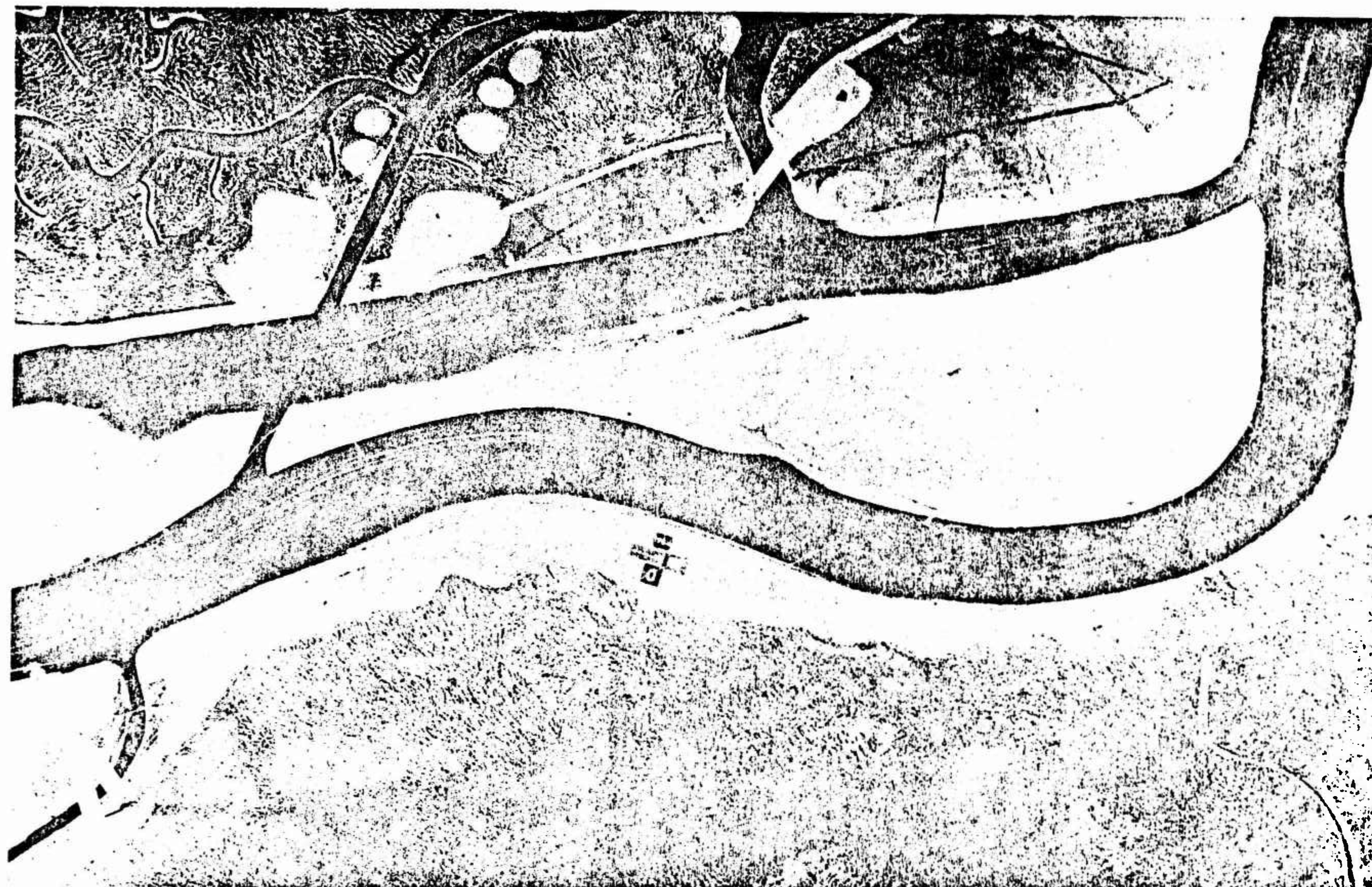
13. It is the opinion of this office that construction of the recommended plan will reduce maximum flood and ebb velocities in the problem area to such extent that no additional measures will be required to protect the right bank of North Channel from further erosion. If construction of the enlarged channel will be performed within the next few years, it is recommended that frequent surveys be made to detect any change in rate of erosion and to indicate any need for emergency protective measures. Erosion control measures should, if possible, be postponed until the wider and deeper channel has been constructed and its effect on the bank erosion has been observed.

Table 1

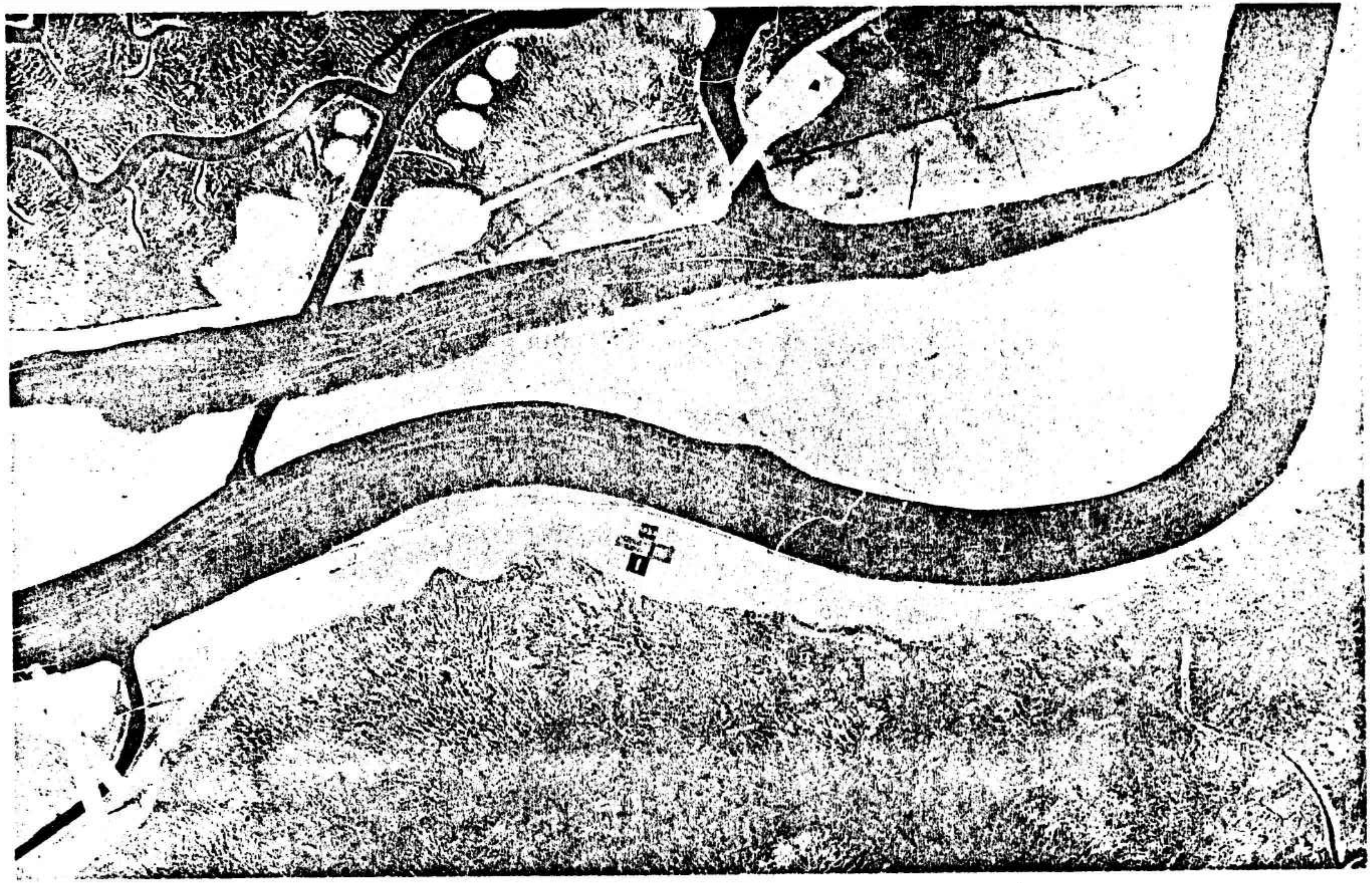
Maximum Current Velocities

		Maximum Current Velocities, fps			
		Ebb Test Conditions		Flood Test Conditions	
Station	Depth*	1964	Phase IX Scheme 4 Test 8	1964	Phase IX Scheme 4 Test 8
151R	S	3.7	3.5	3.3	2.6
	M	2.3	2.4	3.3	2.7
	B	1.7	1.0	3.3	2.3
151L	S	4.5	3.8	2.6	2.6
	M	2.6	2.0	3.1	2.6
	B	2.2	1.9	2.8	2.8
153℄	S	3.8	3.3	2.7	2.6
	M	2.6	2.0	3.7	3.4
	B	2.2	0.7	2.4	2.2
155R	S	4.2	3.4	3.1	2.6
	M	2.8	2.0	3.7	2.6
	B	1.7	1.2	3.3	2.6
155L	S	4.0	3.7	2.8	2.0
	M	2.7	2.3	3.0	3.1
	B	2.2	1.2	2.6	2.8
157R	S	3.9	4.0	3.4	2.6
	M	2.8	2.3	3.5	2.8
	B	2.6	1.2	3.4	2.5
157L	S	4.4	3.8	3.3	2.8
	M	2.8	2.0	3.4	3.4
	B	2.0	1.7	3.1	2.3
159R	S	4.4	4.2	3.4	3.1
	M	3.2	2.6	3.2	3.1
	B	2.3	1.6	3.1	2.6
159L	S	4.7	4.1	3.7	3.4
	M	2.9	2.3	3.4	3.3
	B	1.8	1.3	3.1	3.4
161R	S	5.2	4.7	2.9	2.8
	M	3.4	4.0	2.9	3.4
	B	2.9	2.3	2.8	2.8
161L	S	4.2	4.2	3.4	3.1
	M	3.2	2.8	3.4	3.4
	B	2.3	1.8	2.8	2.6
163R	S	5.2	4.6	2.7	1.9
	M	3.6	2.4	3.2	3.2
	B	2.8	1.6	2.3	2.6
163L	S	4.4	4.2	3.4	2.6
	M	2.6	2.4	2.6	2.9
	B	2.0	1.6	2.6	3.1
163℄	S	4.4	4.5	2.9	2.4
	M	2.4	2.1	3.5	2.9
	B	2.3	1.6	2.3	2.3

* S = surface; M = middepth; B = bottom.

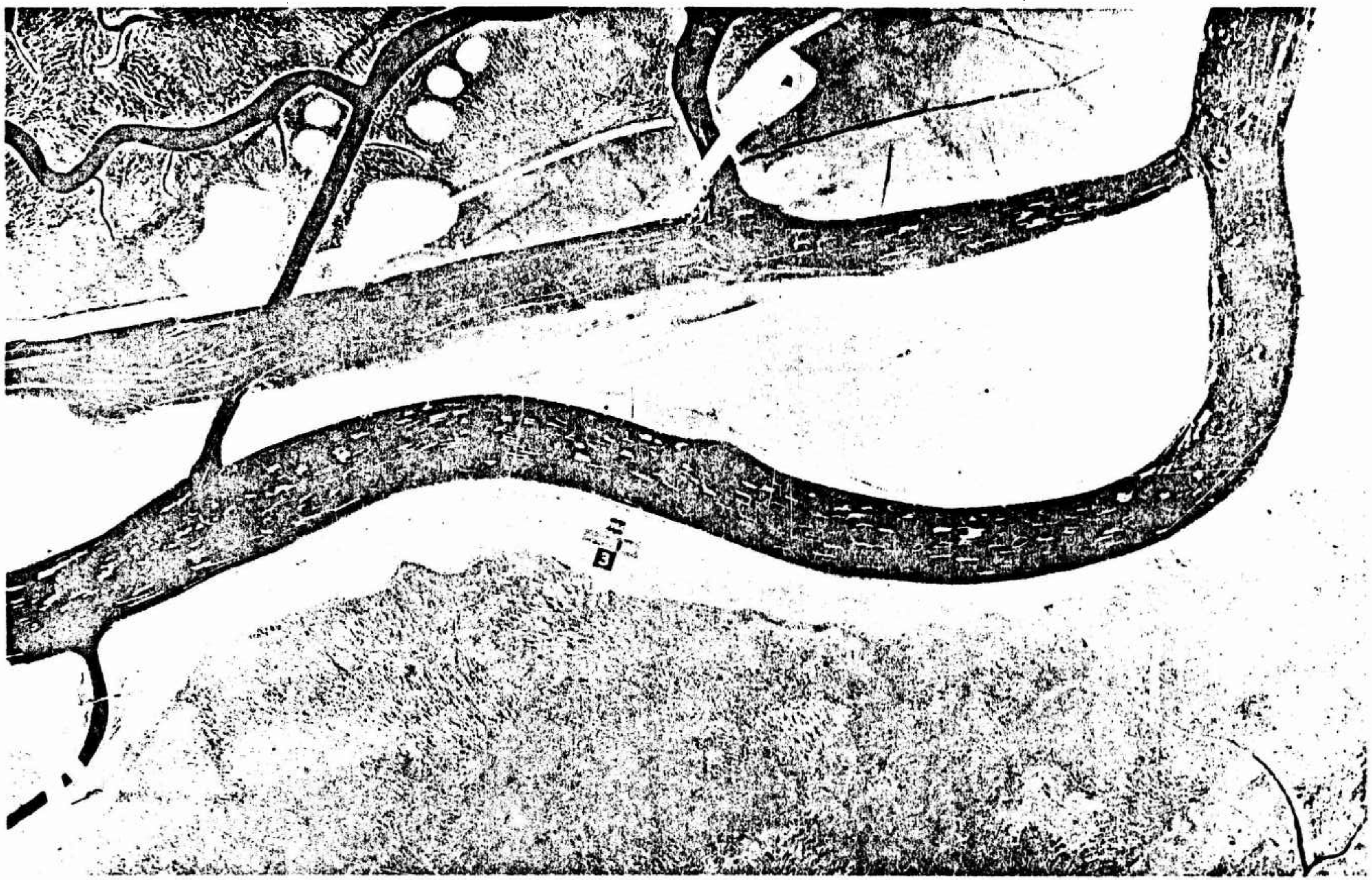


Photograph 1. Surface current directions and velocities for 1964 channel conditions. Hour 0, ebb tide

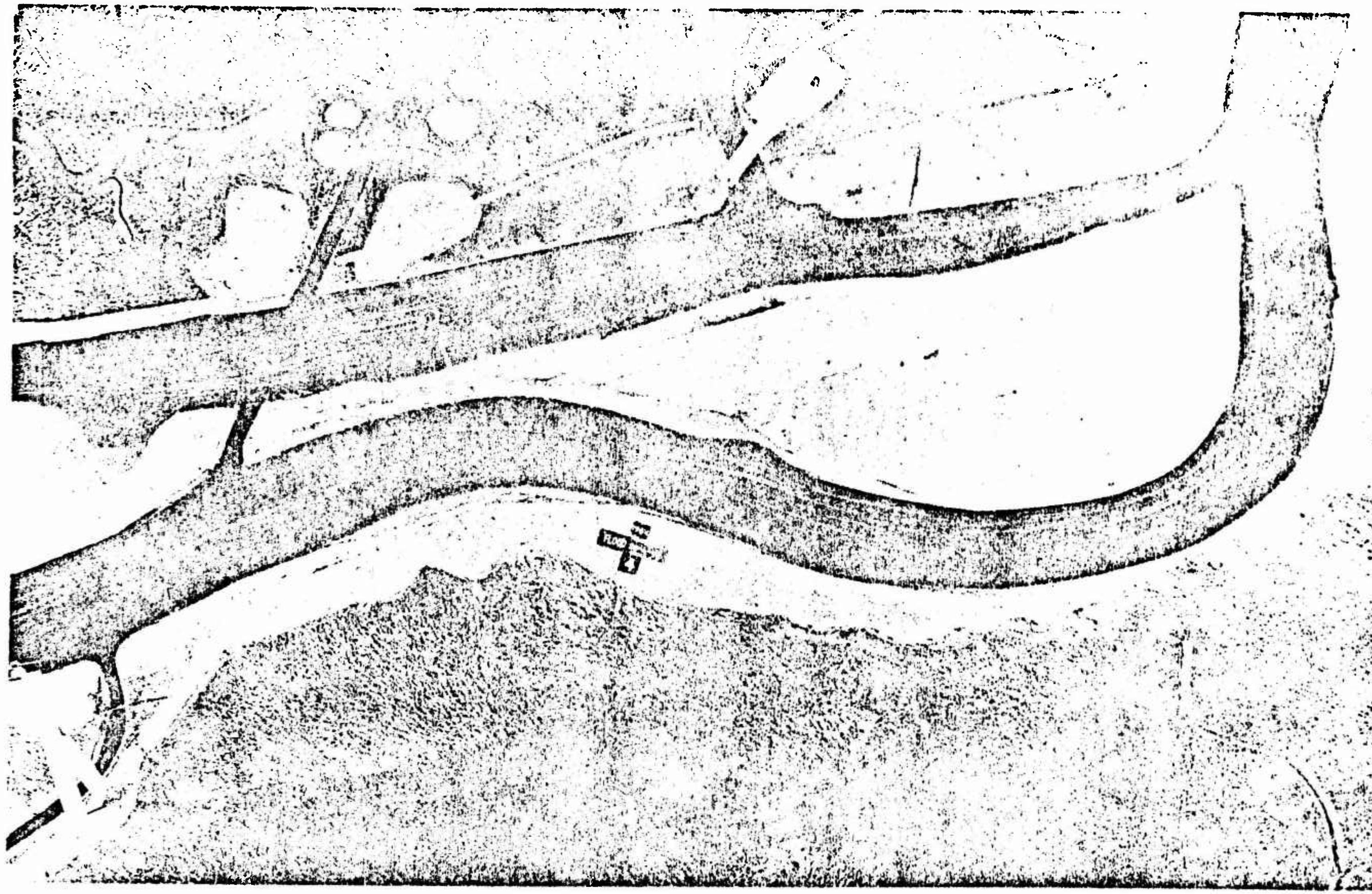


Photograph 2. Surface current directions and velocities for 1964 channel conditions. Hour 1, ebb tide

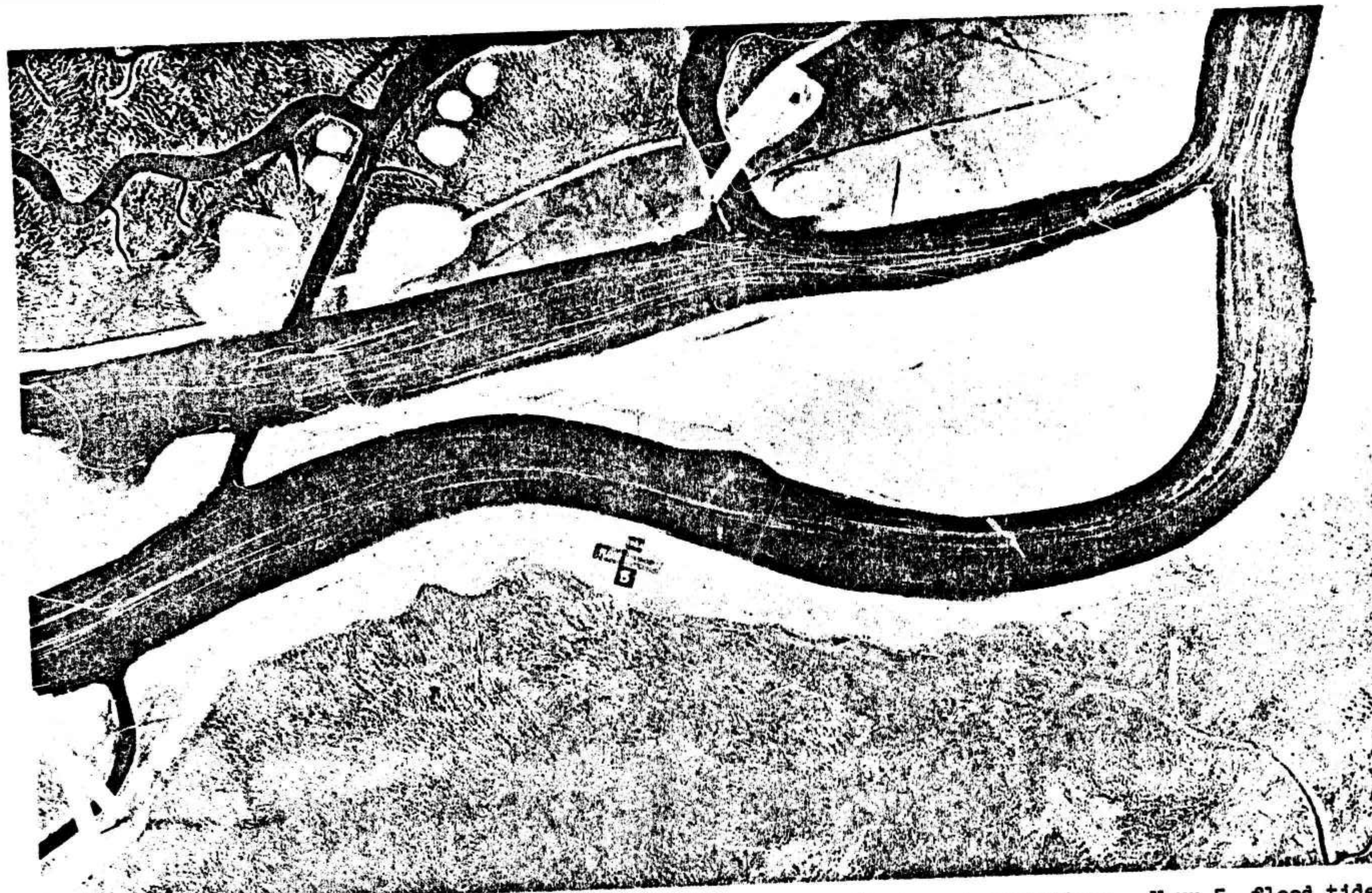
Photograph 3. Surface current directions and velocities for 1964 channel conditions. Hour 2, ebb tide



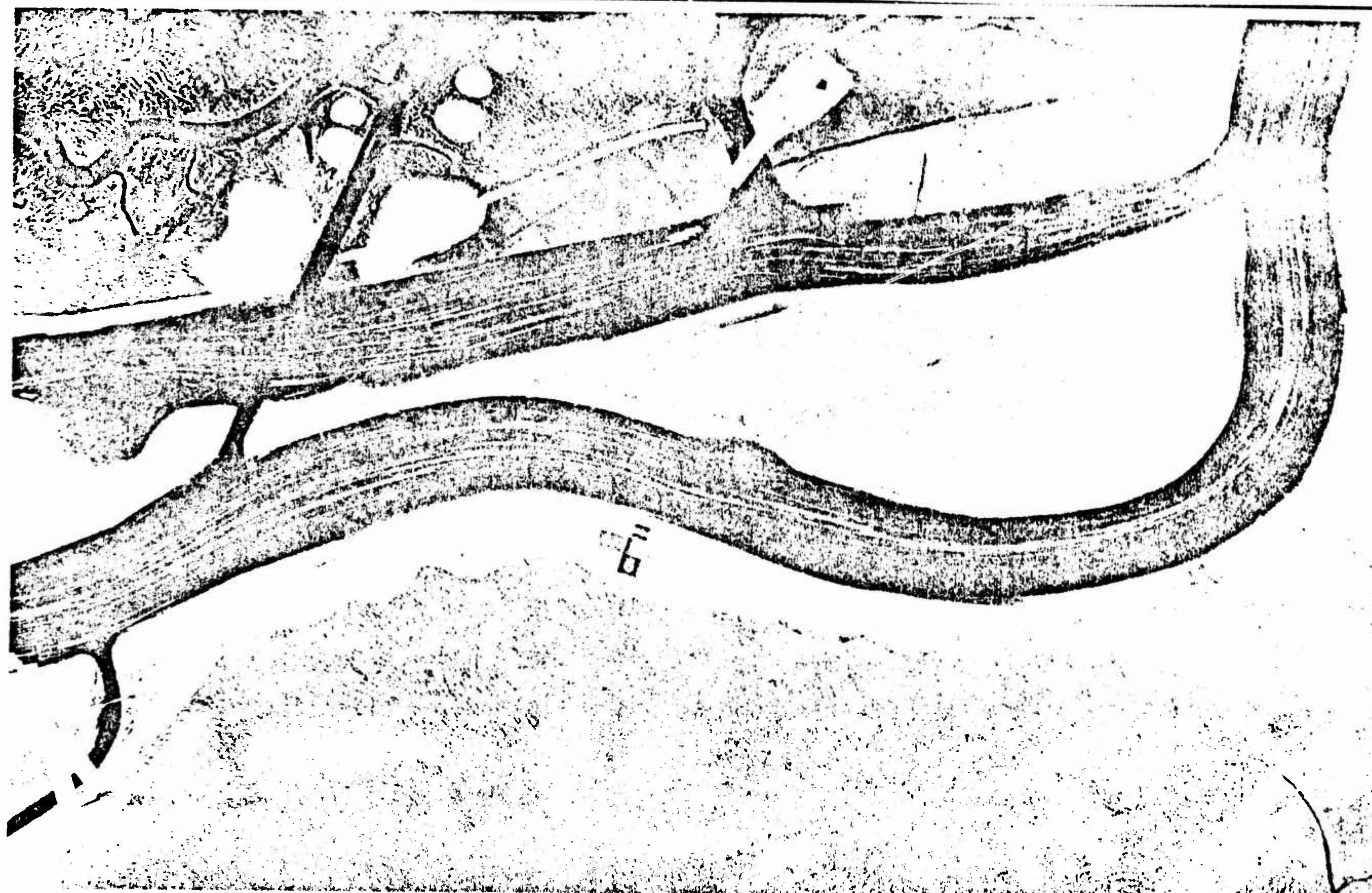
Photograph 4. Surface current directions and velocities for 1964 channel conditions. Hour 3, ebb tide



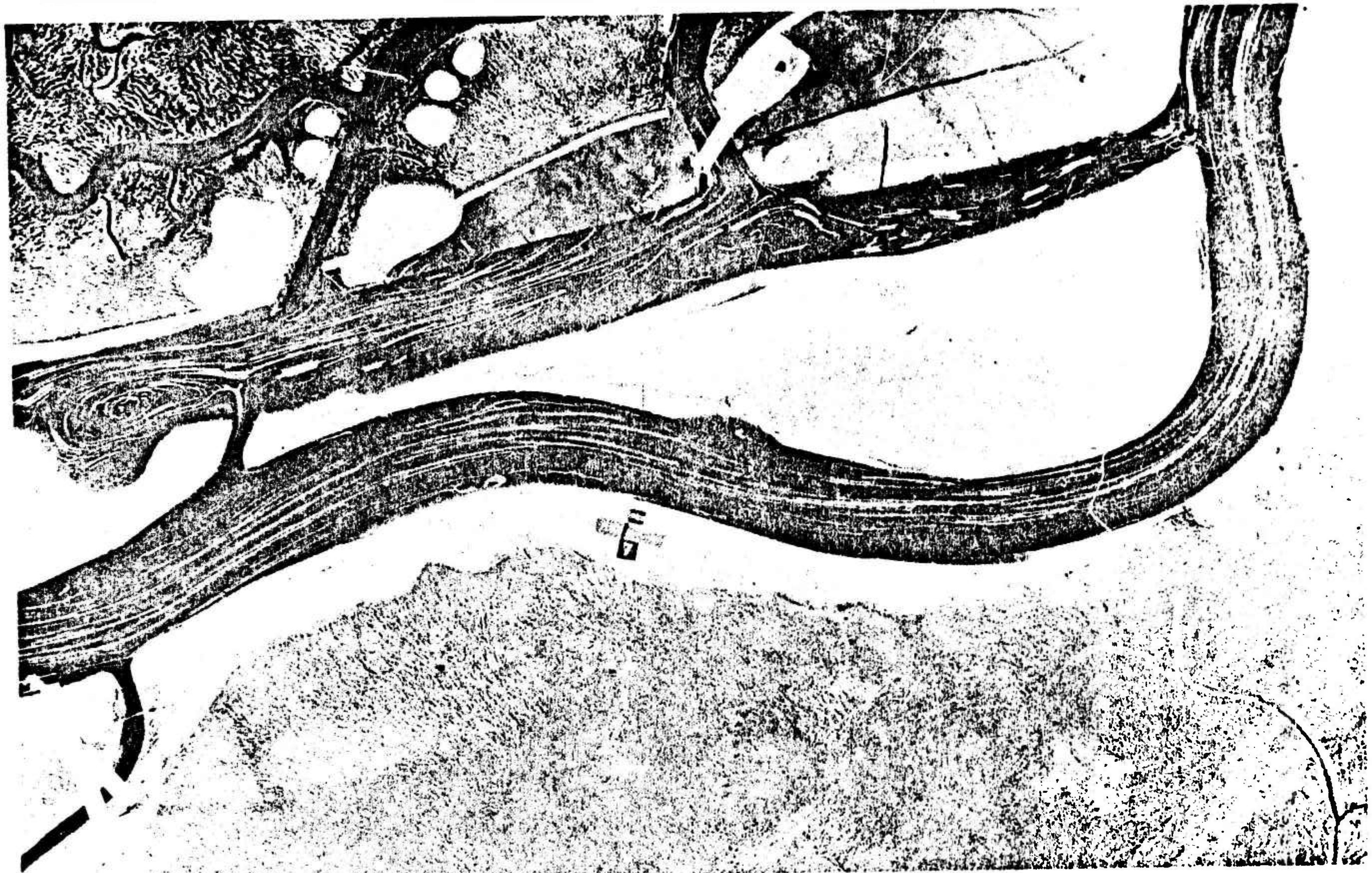
Photograph 5. Surface current directions and velocities for 1964 channel conditions. Hour 4, flood tide



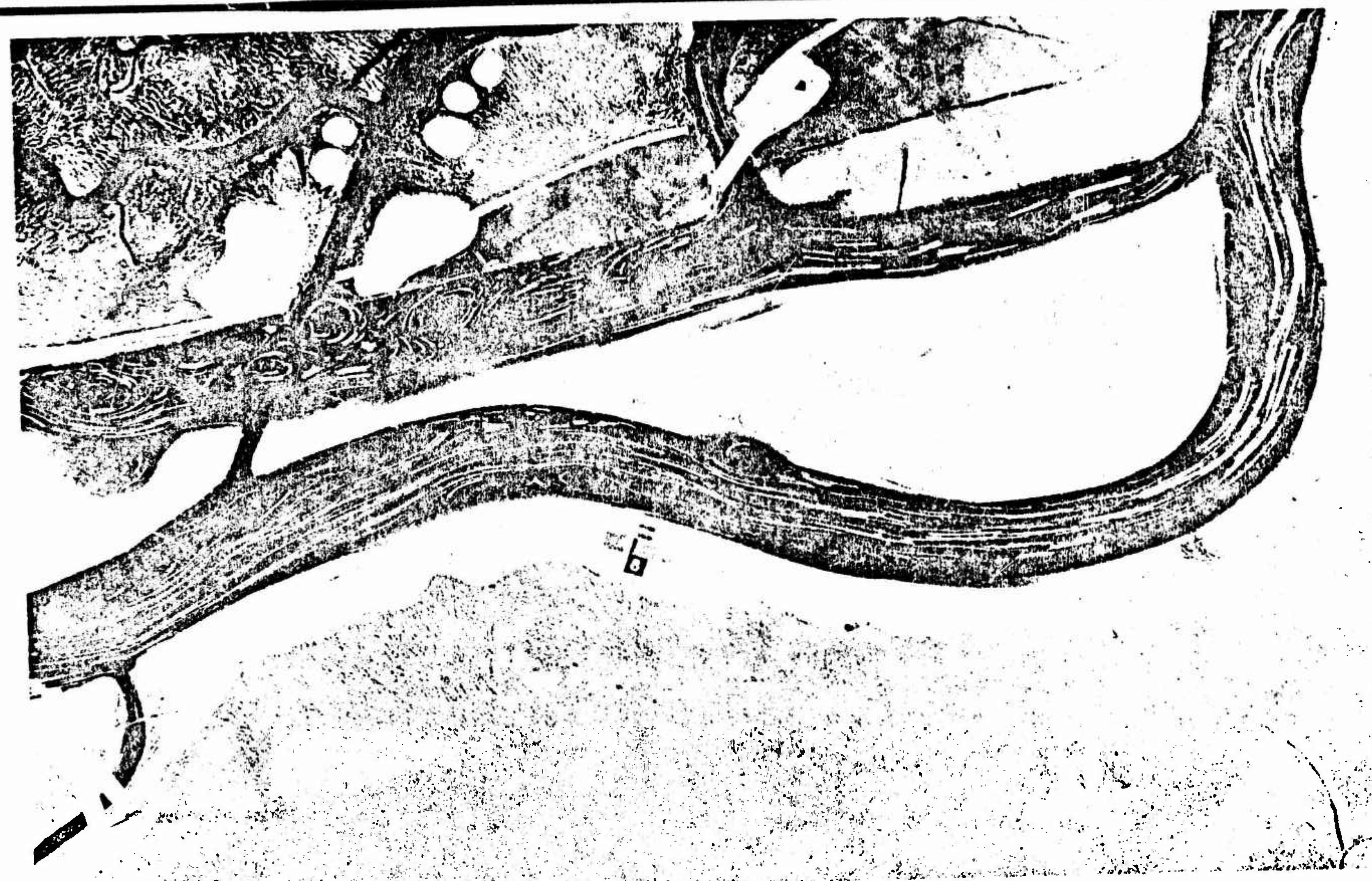
Photograph 6. Surface current directions and velocities for 1964 channel conditions. Hour 5, flood tide



Photograph 7. Surface current directions and velocities for 1964 channel conditions. Hour 6, flood tide

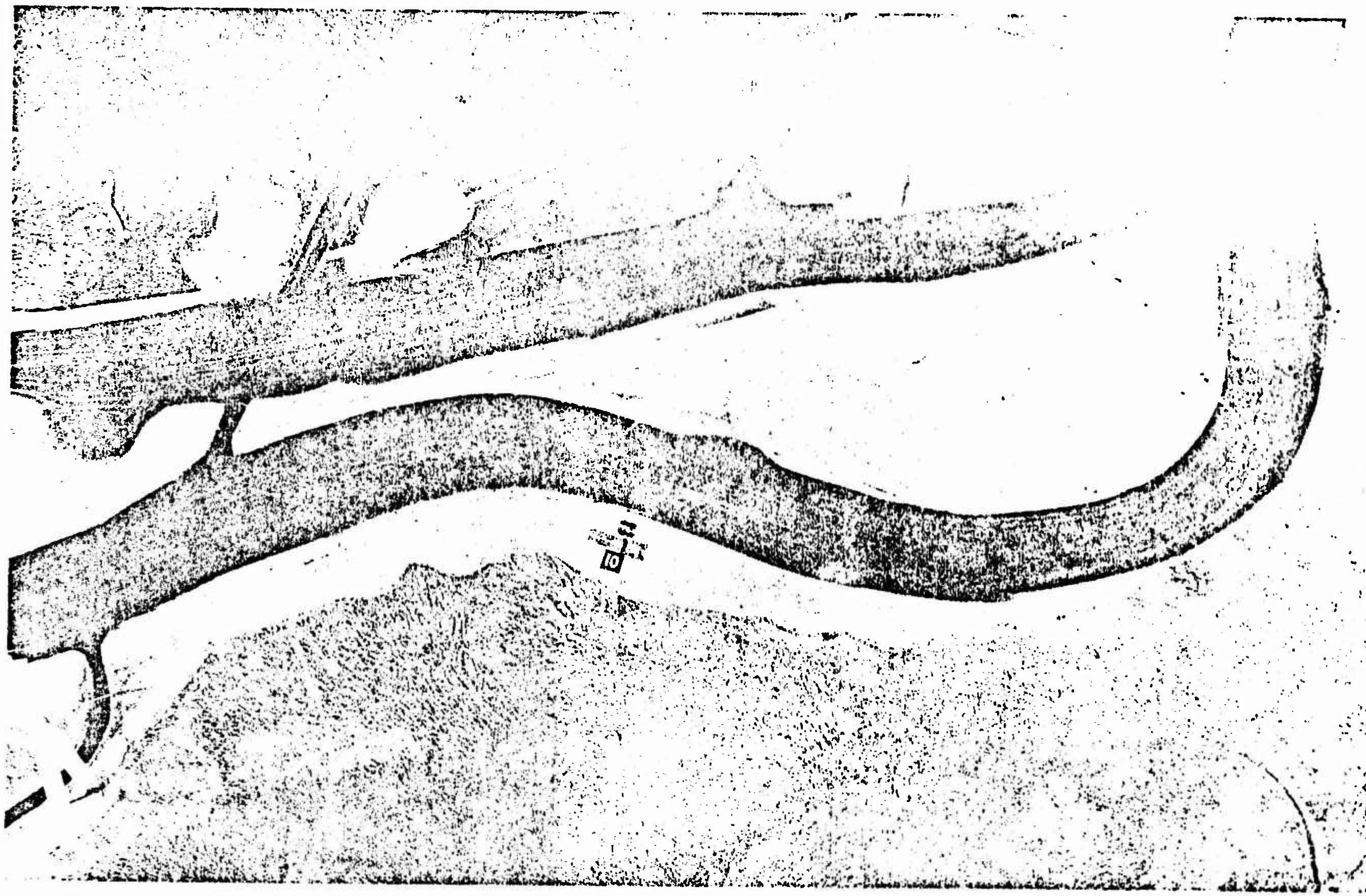


Photograph 8. Surface current directions and velocities for 1964 channel conditions. Hour 7, flood tide

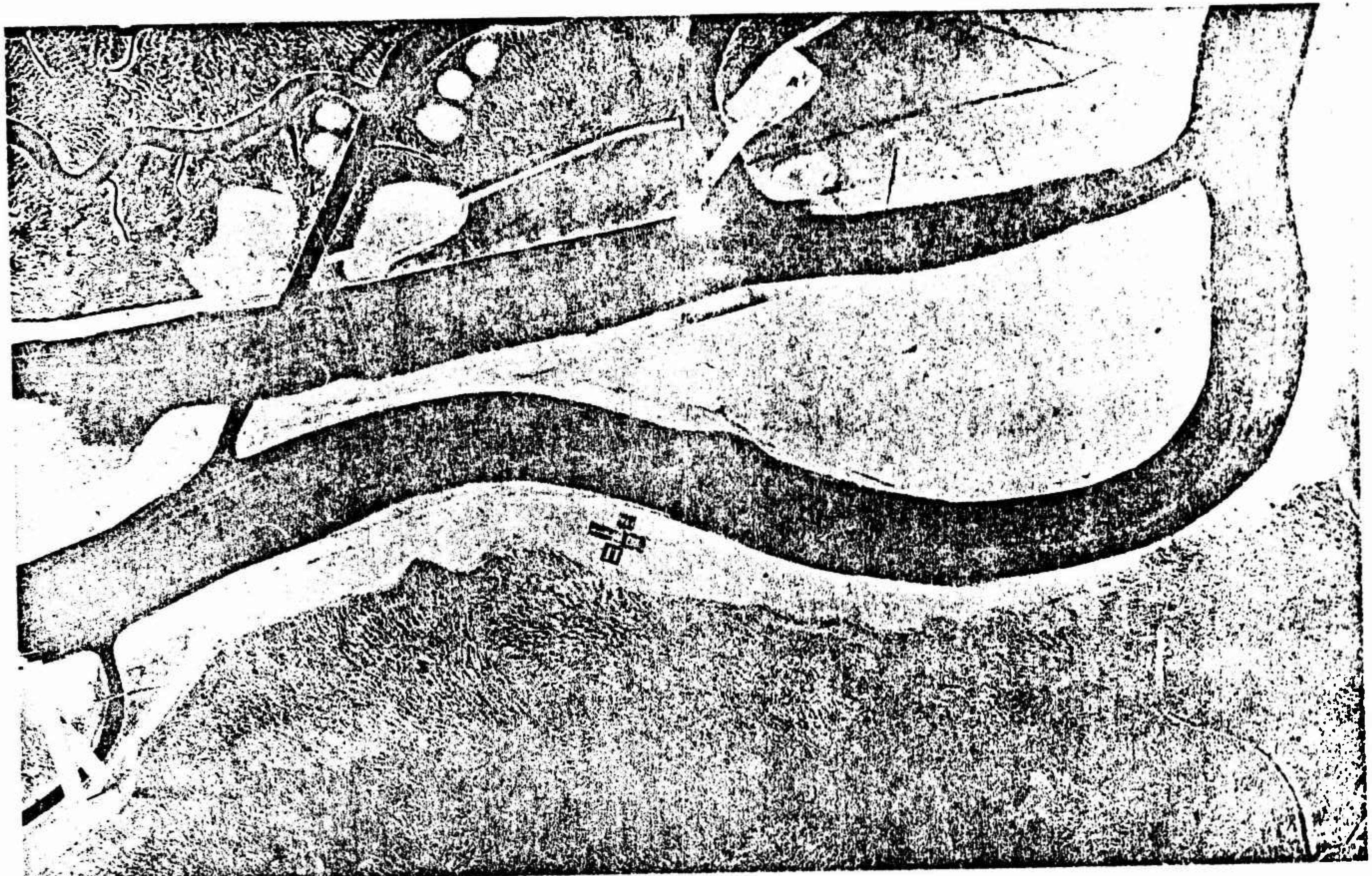


Photograph 9. Surface current directions and velocities for 1964 channel conditions. Hour 8, flood tide

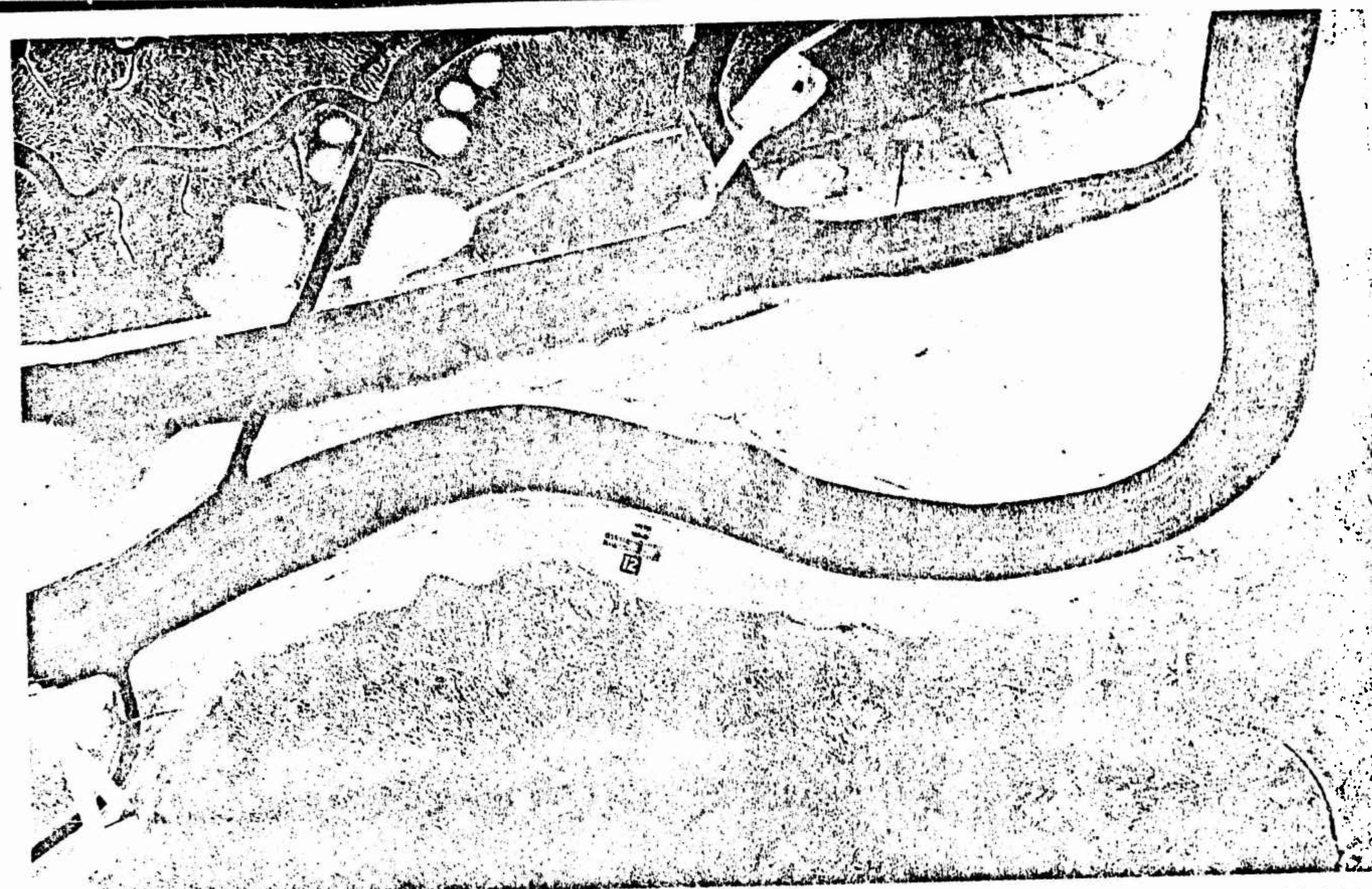
Photograph 10. Surface current directions and velocities for 1964 channel conditions. Hour 9, ebb tide



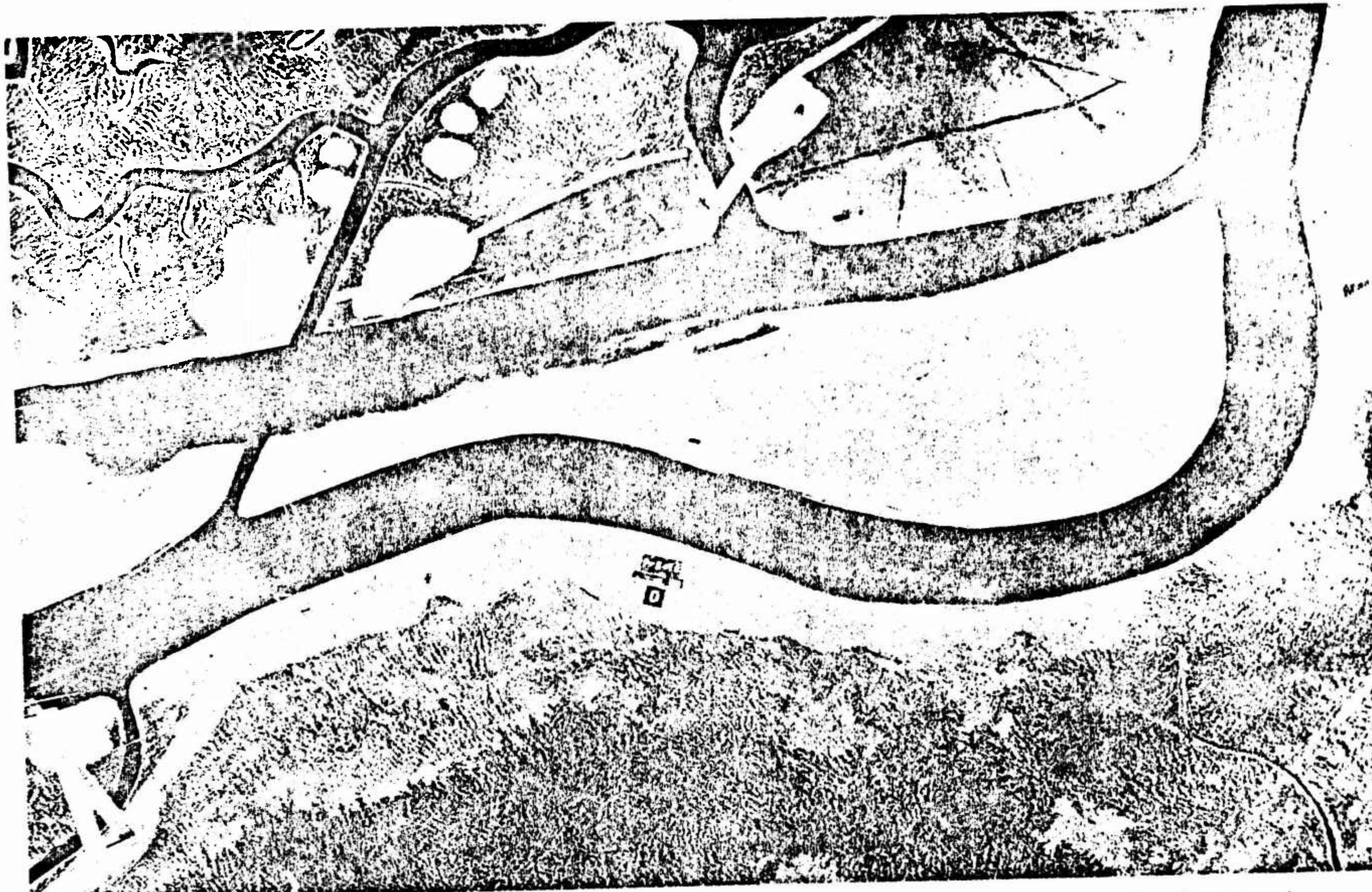
Photograph 11. Surface current directions and velocities for 1964 channel conditions. Hour 10, ebb tide



Photograph 12. Surface current directions and velocities for 1964 channel conditions. Hour 11, ebb tide



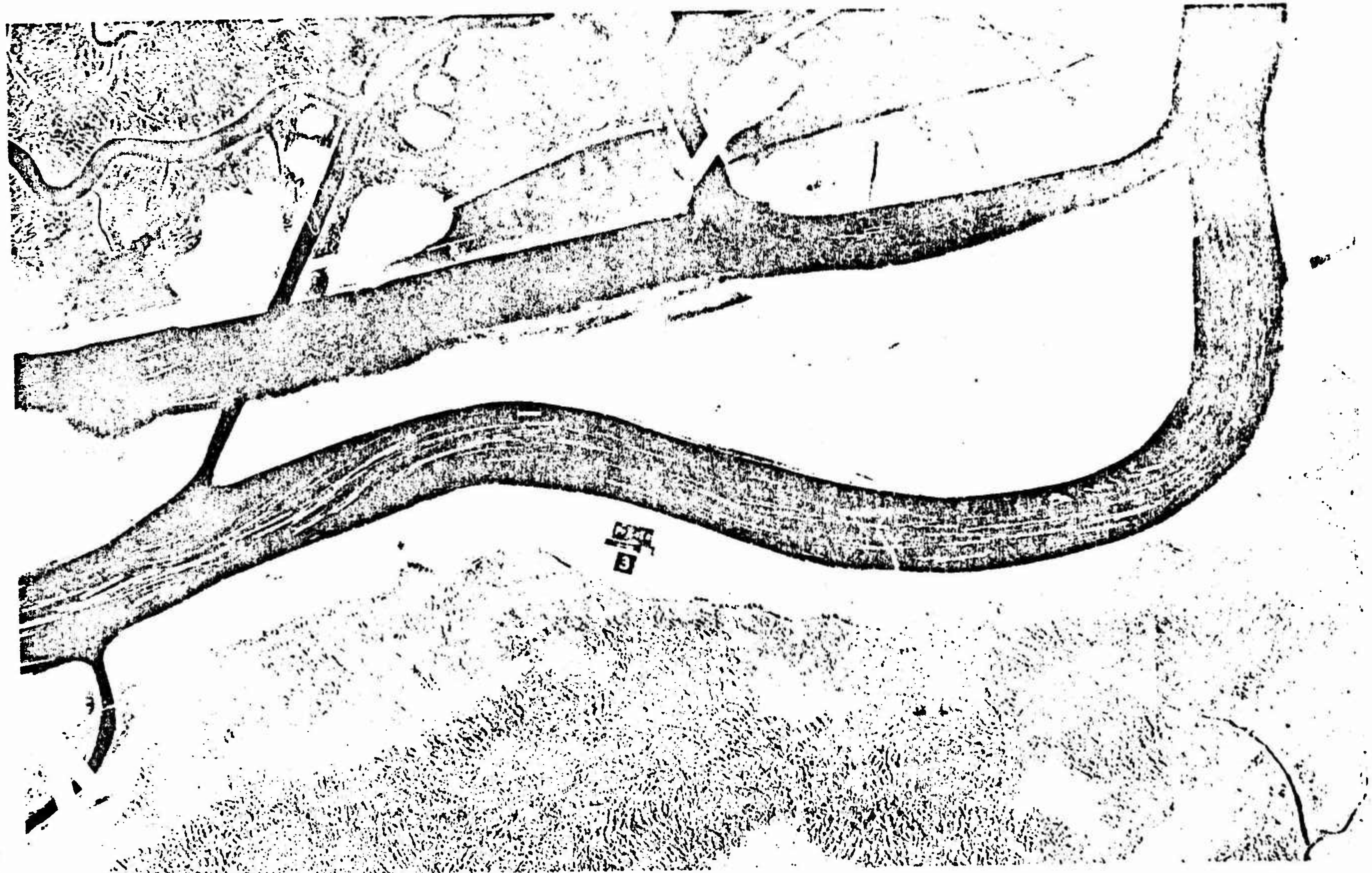
Photograph 13. Surface current directions and velocities for 1964 channel conditions. Hour 12, ebb tide



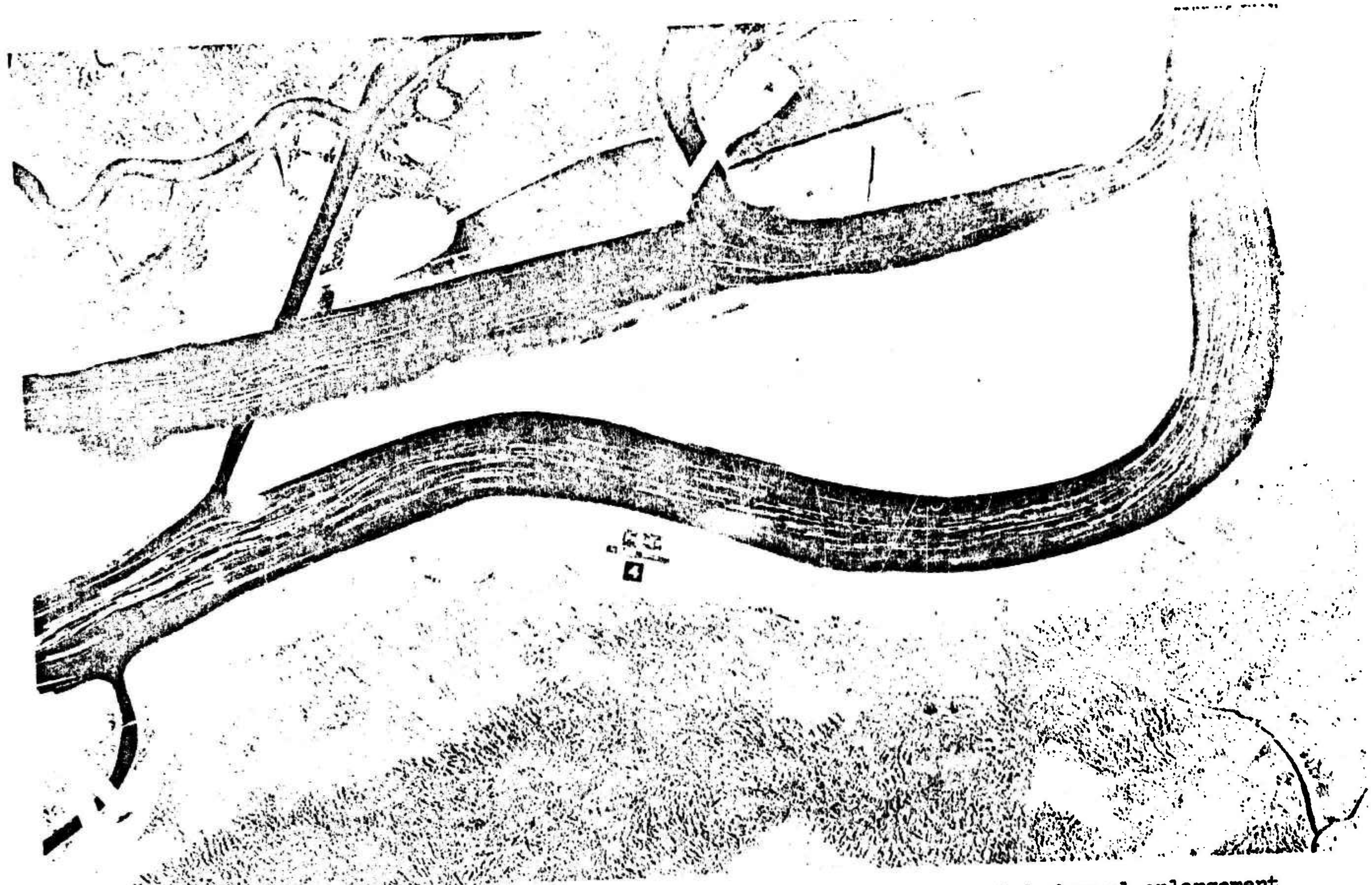
Photograph 14. Surface current directions and velocities for recommended channel enlargement.
Hour 0, ebb tide

Photograph 15. Surface current directions and velocities for recommended channel enlargement.
Hour 1, ebb tide

Photograph 16. Surface current directions and velocities for recommended channel enlargement.
Hour 2, ebb tide

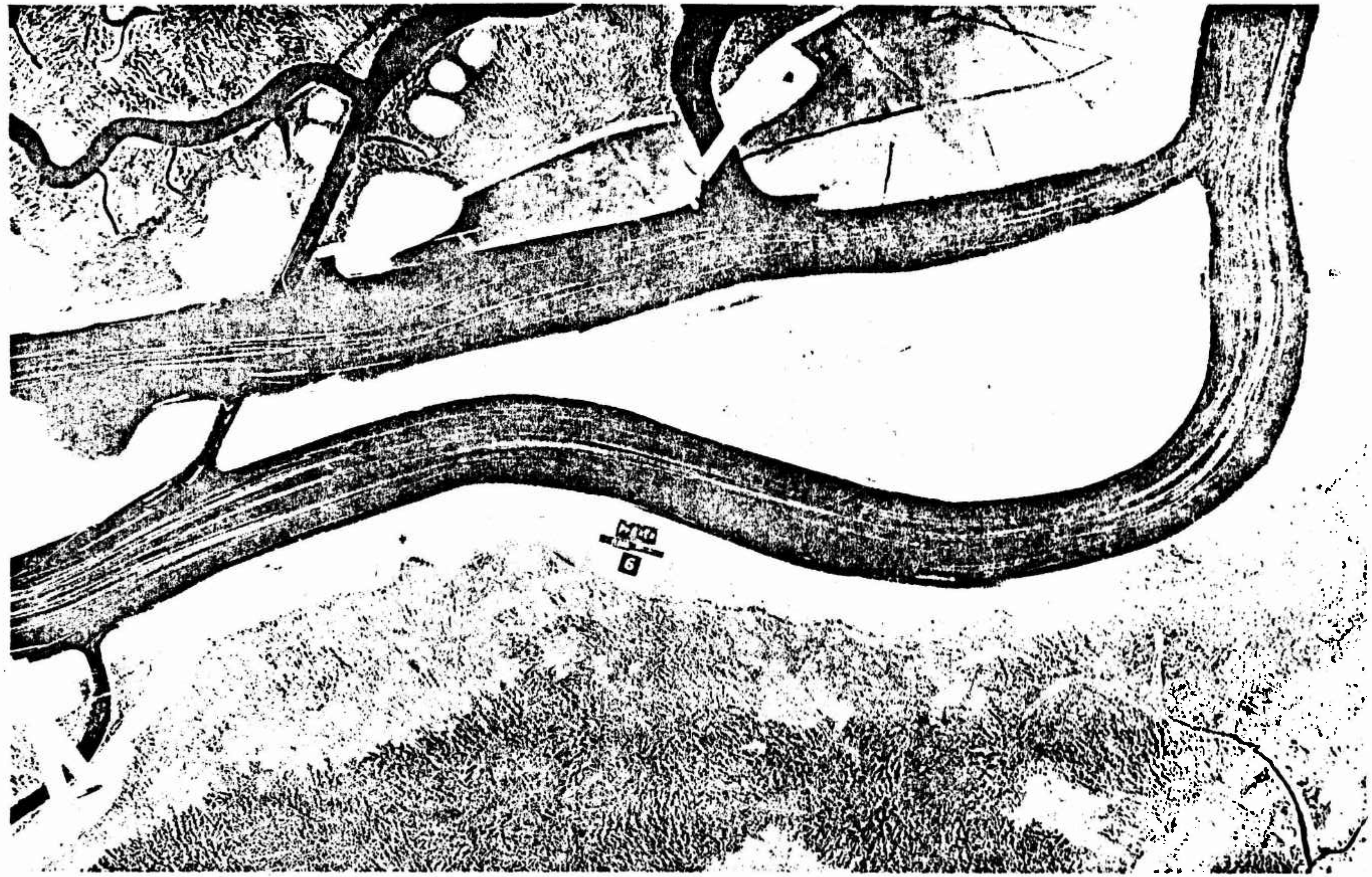


Photograph 17. Surface current directions and velocities for recommended channel enlargement. Hour 3, ebb tide



Photograph 18. Surface current directions and velocities for recommended channel enlargement. Hour 4, flood tide

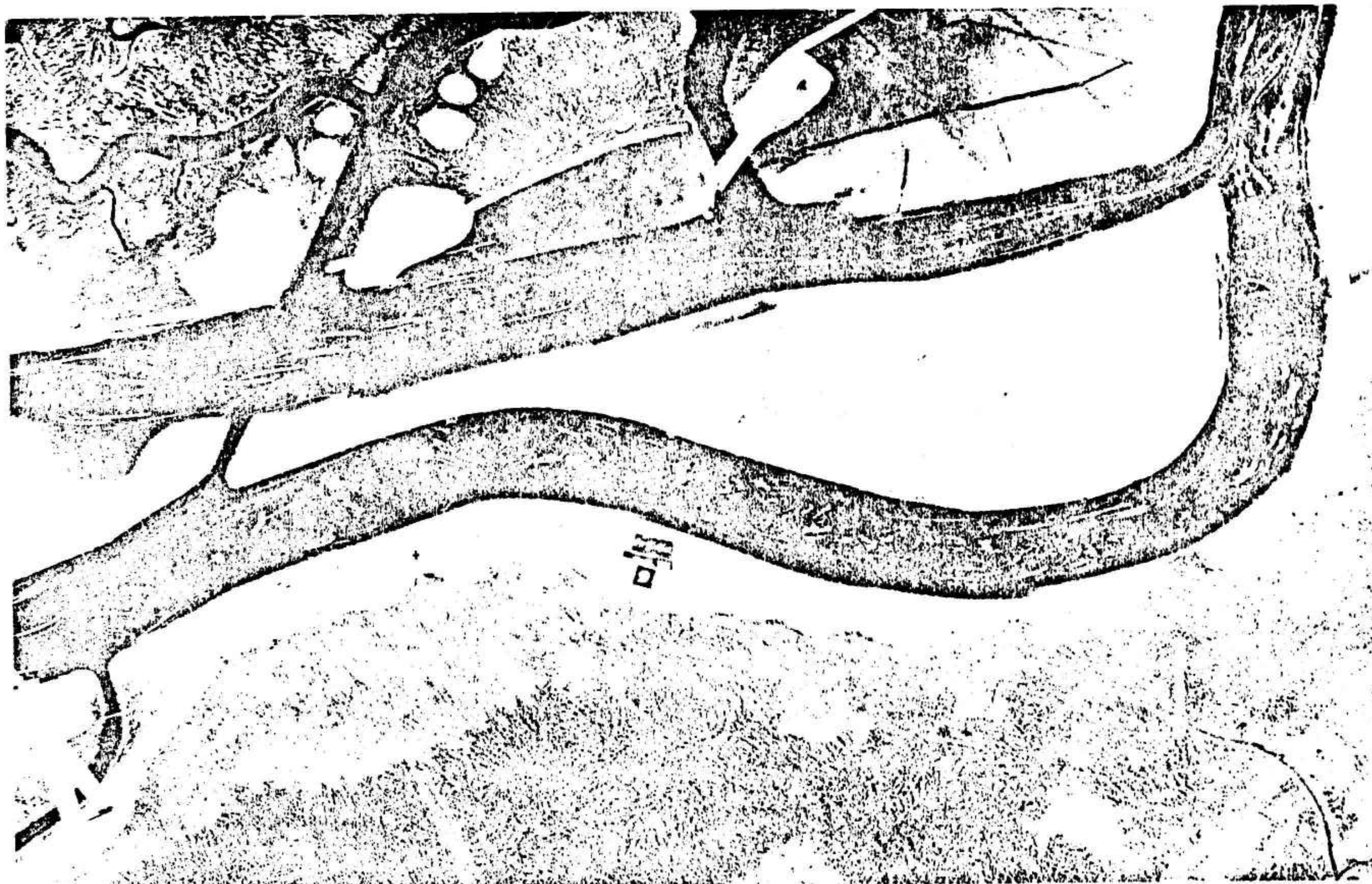
Photograph 19. Surface current directions and velocities for recommended channel enlargement. Hour 5, flood tide



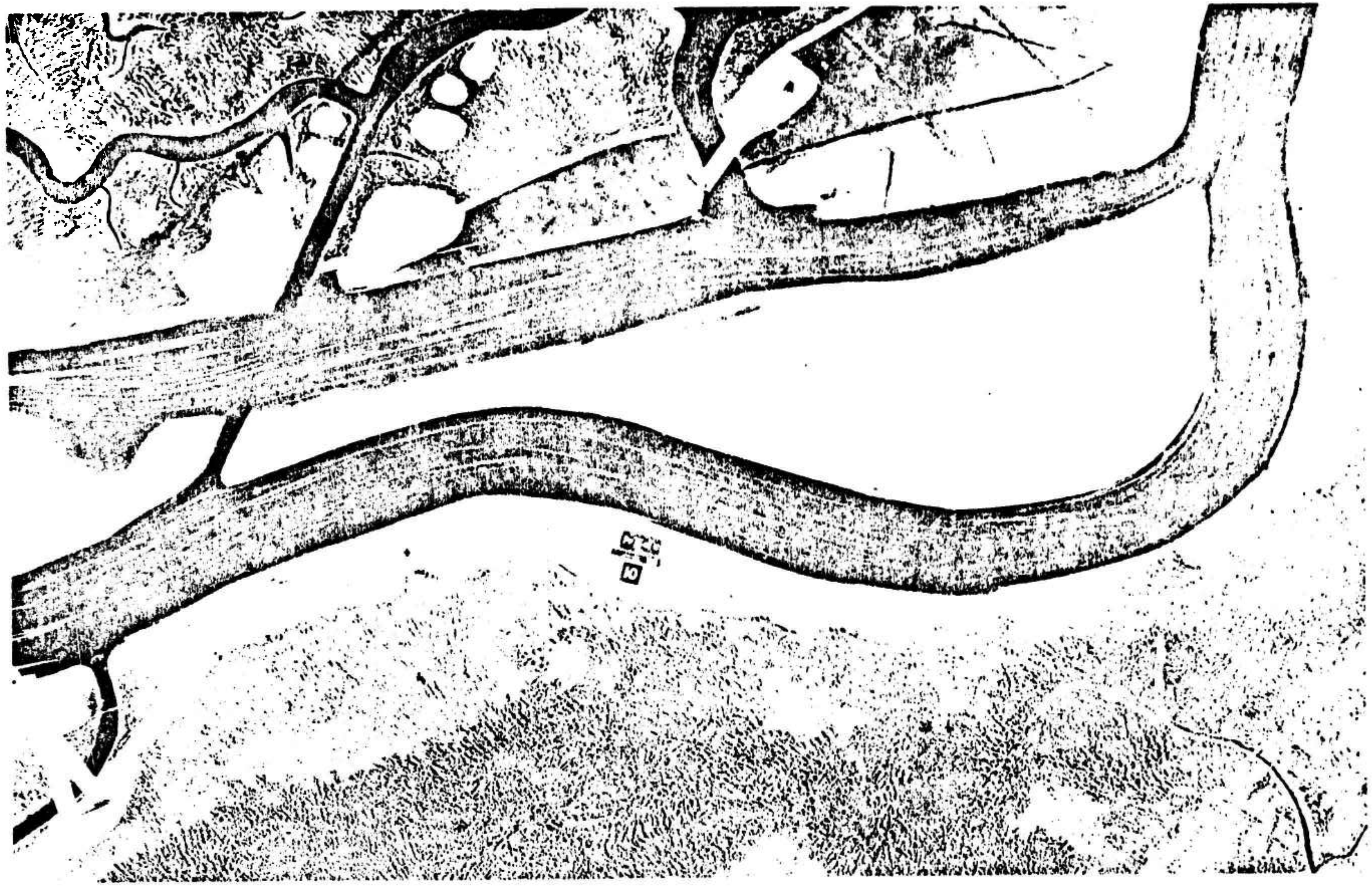
Photograph 20. Surface current directions and velocities for recommended channel enlargement. Hour 6, flood tide

Photograph 21. Surface current directions and velocities for recommended channel enlargement. Hour 7, flood tide

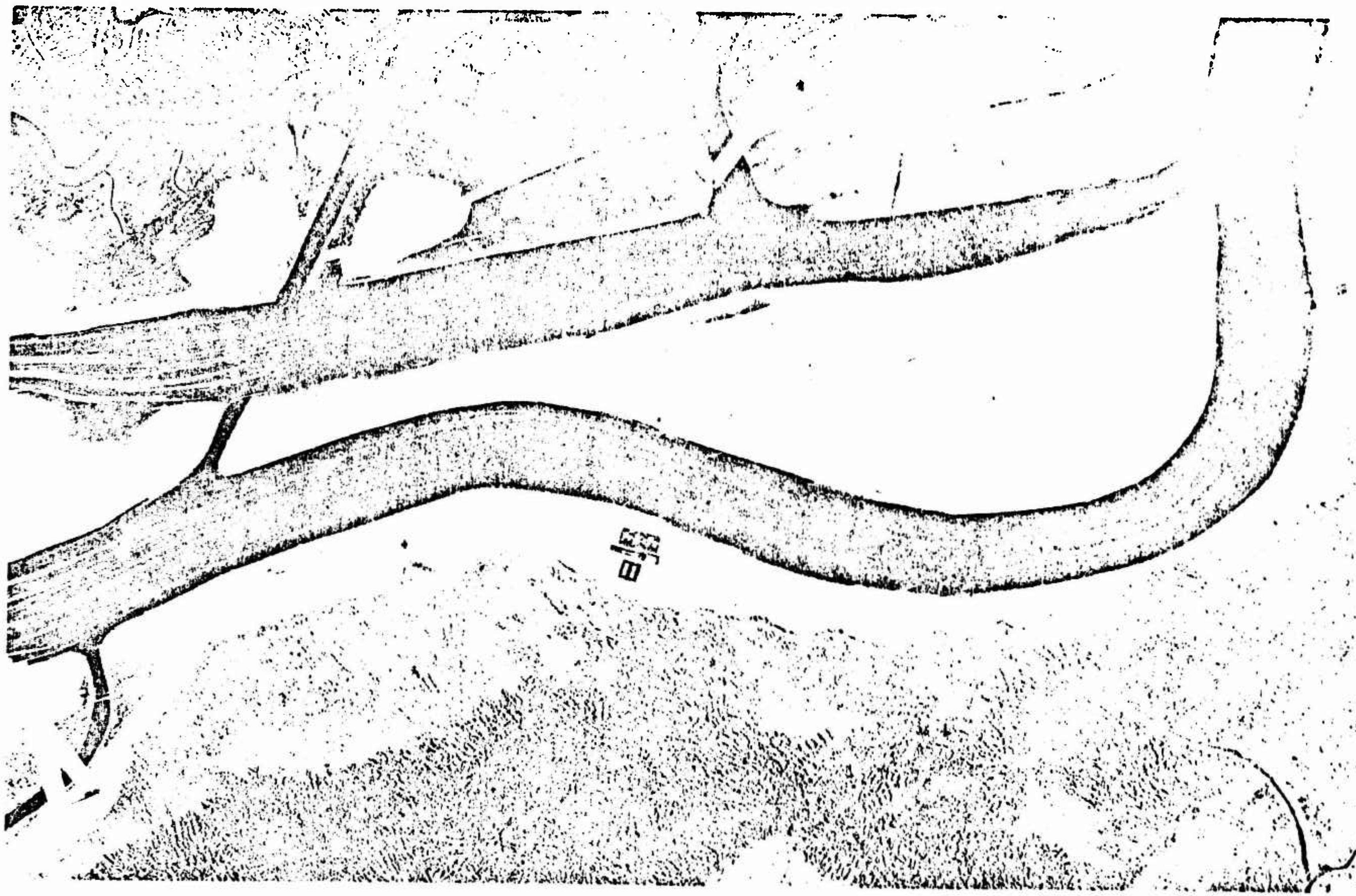
Photograph 22. Surface current directions and velocities for recommended channel enlargement. Hour 8, flood tide



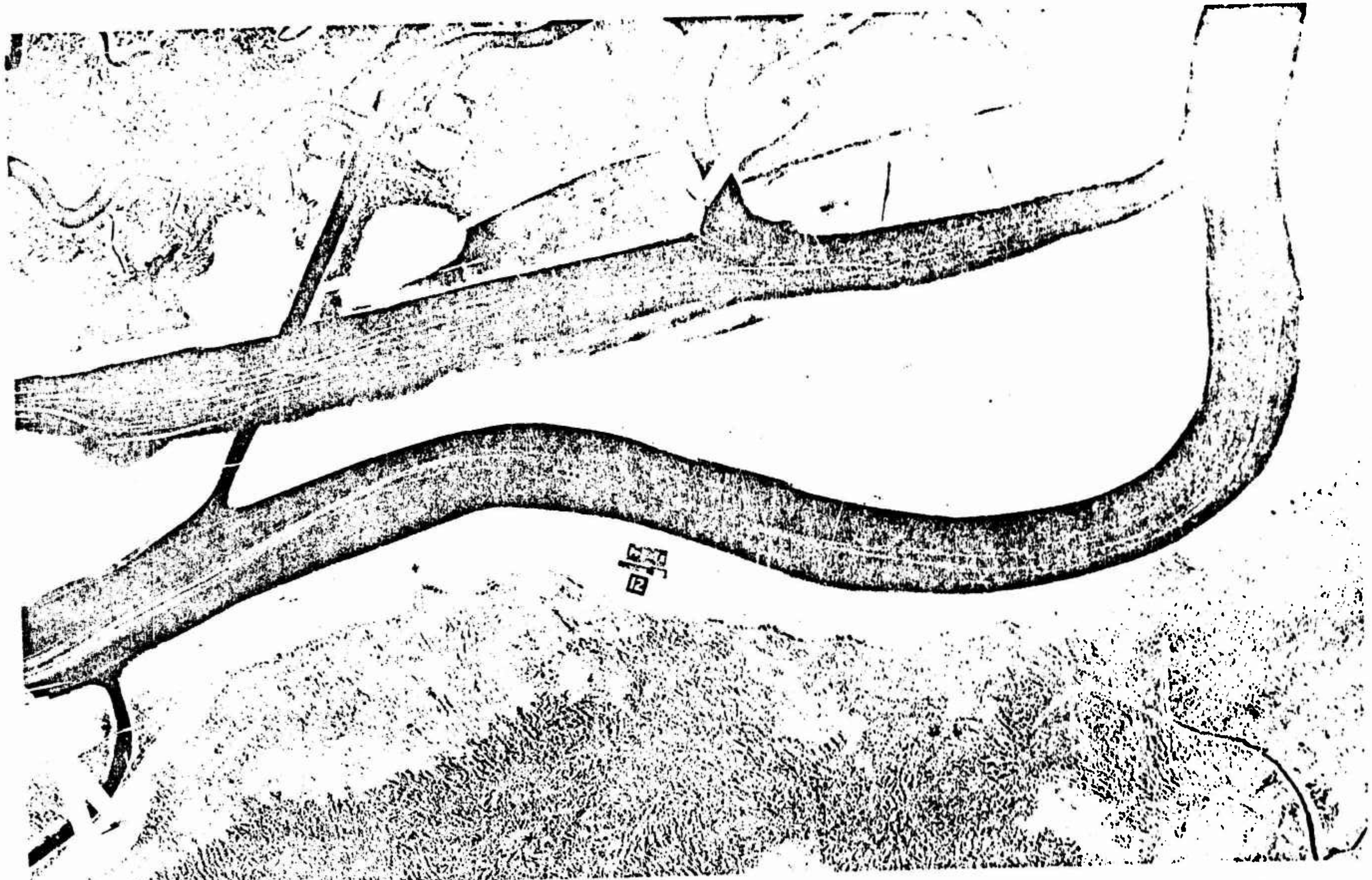
Photograph 23. Surface current directions and velocities for recommended channel enlargement.
Hour 9, ebb tide



Photograph 24. Surface current directions and velocities for recommended channel enlargement.
Hour 10, ebb tide



Photograph 25. Surface current directions and velocities for recommended channel enlargement. Hour 11, ebb tide



Photograph 26. Surface current directions and velocities for recommended channel enlargement. Hour 12, ebb tide

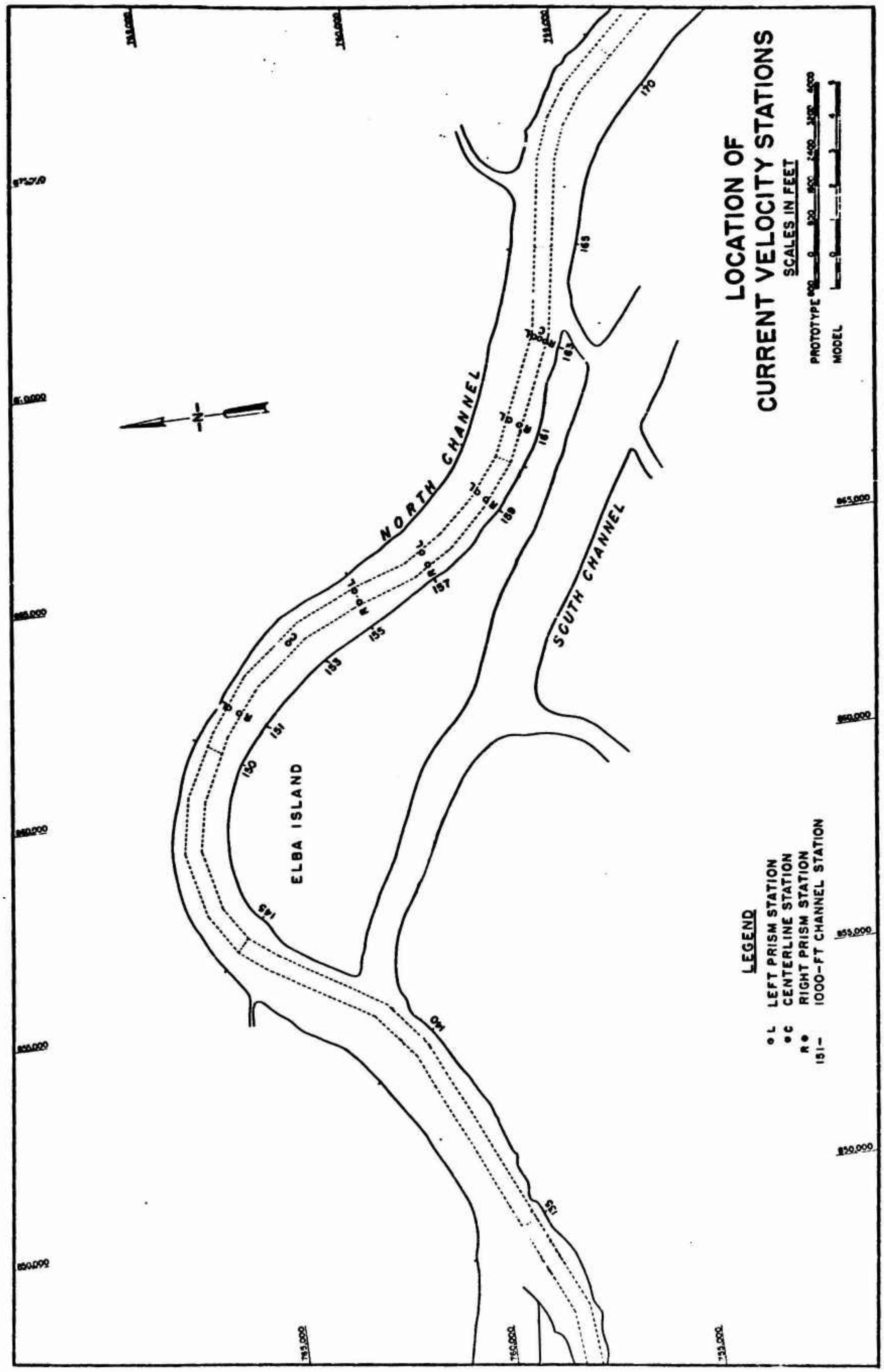
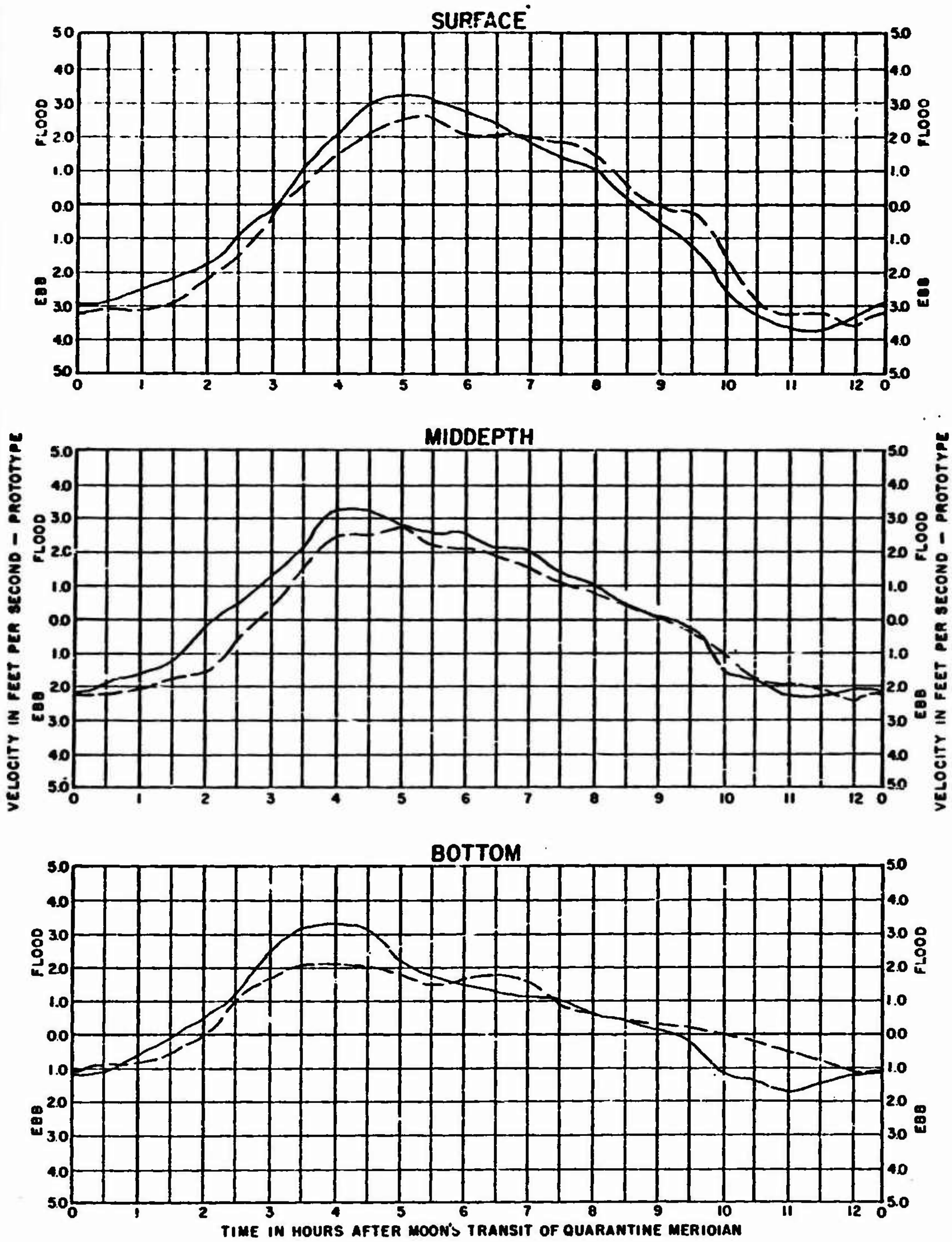

LOCATION OF
CURRENT VELOCITY STATIONS
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
L LEFT PRISM STATION
C CENTERLINE STATION
R RIGHT PRISM STATION
151- 1000-FT CHANNEL STATION
NORTH CHANNEL
SOUTH CHANNEL
ELBA ISLAND

PLATE I



MODEL TEST DATA

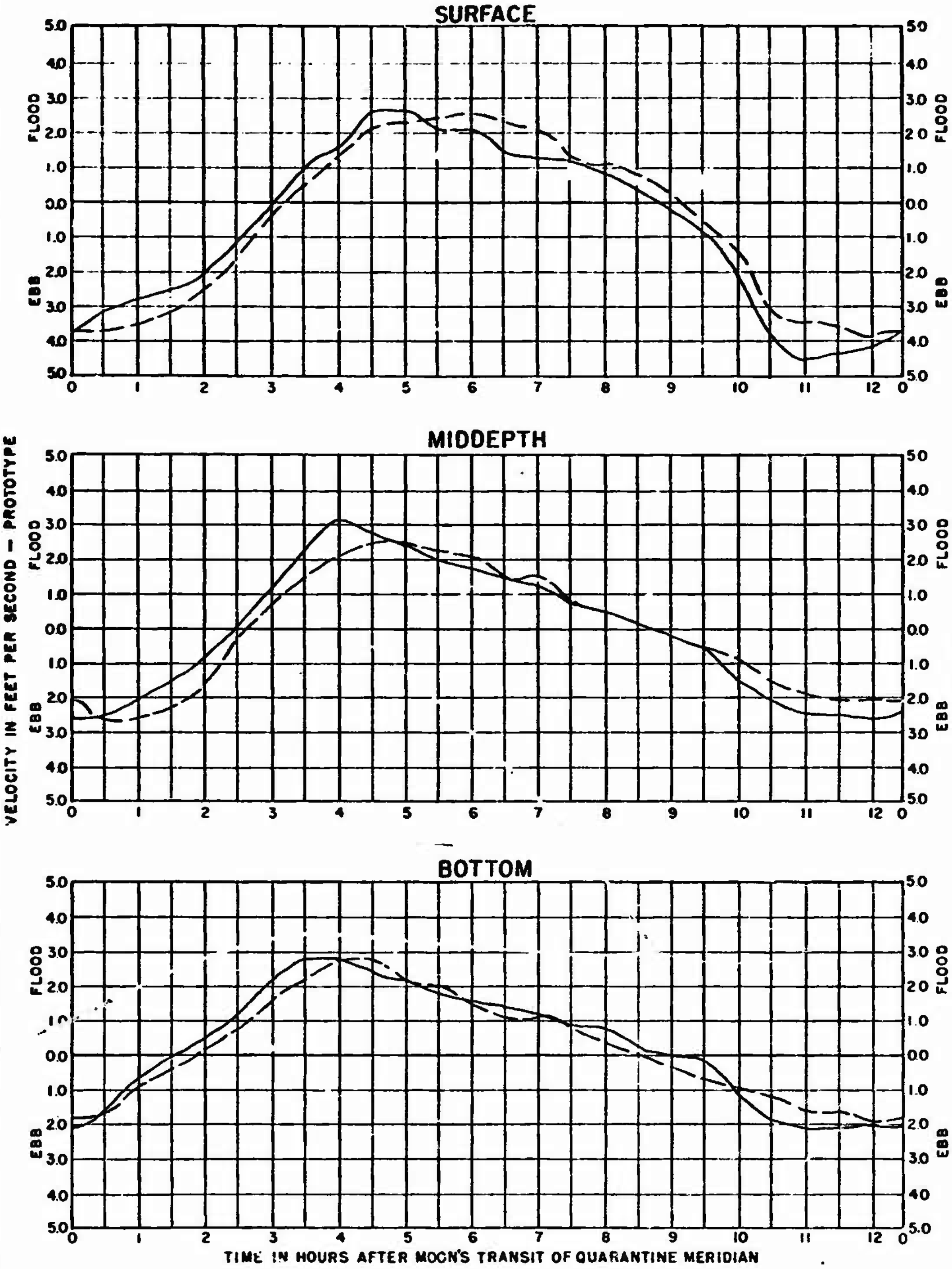
TIDE .... MEAN
FRESH-WATER DISCHARGE ... 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

— — —·— — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 151 RIGHT PRISM

PLATE 2



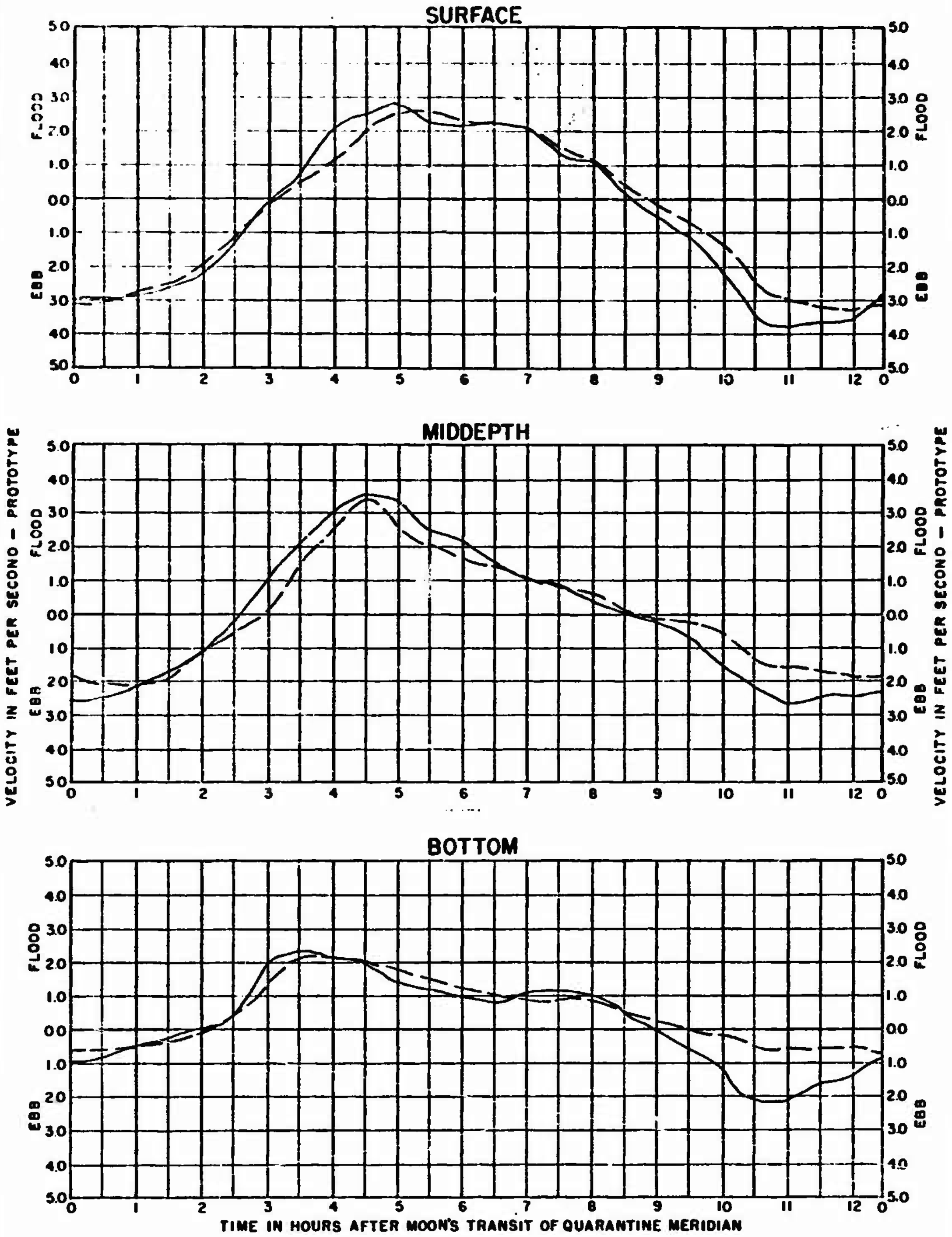
MODEL TEST DATA

TIDE .... MEAN
FRESH-WATER DISCHARGE ... 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

— — — — PHASE IX, SCHEME 4, TEST 8
———— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 151 LEFT PRISM



MODEL TEST DATA

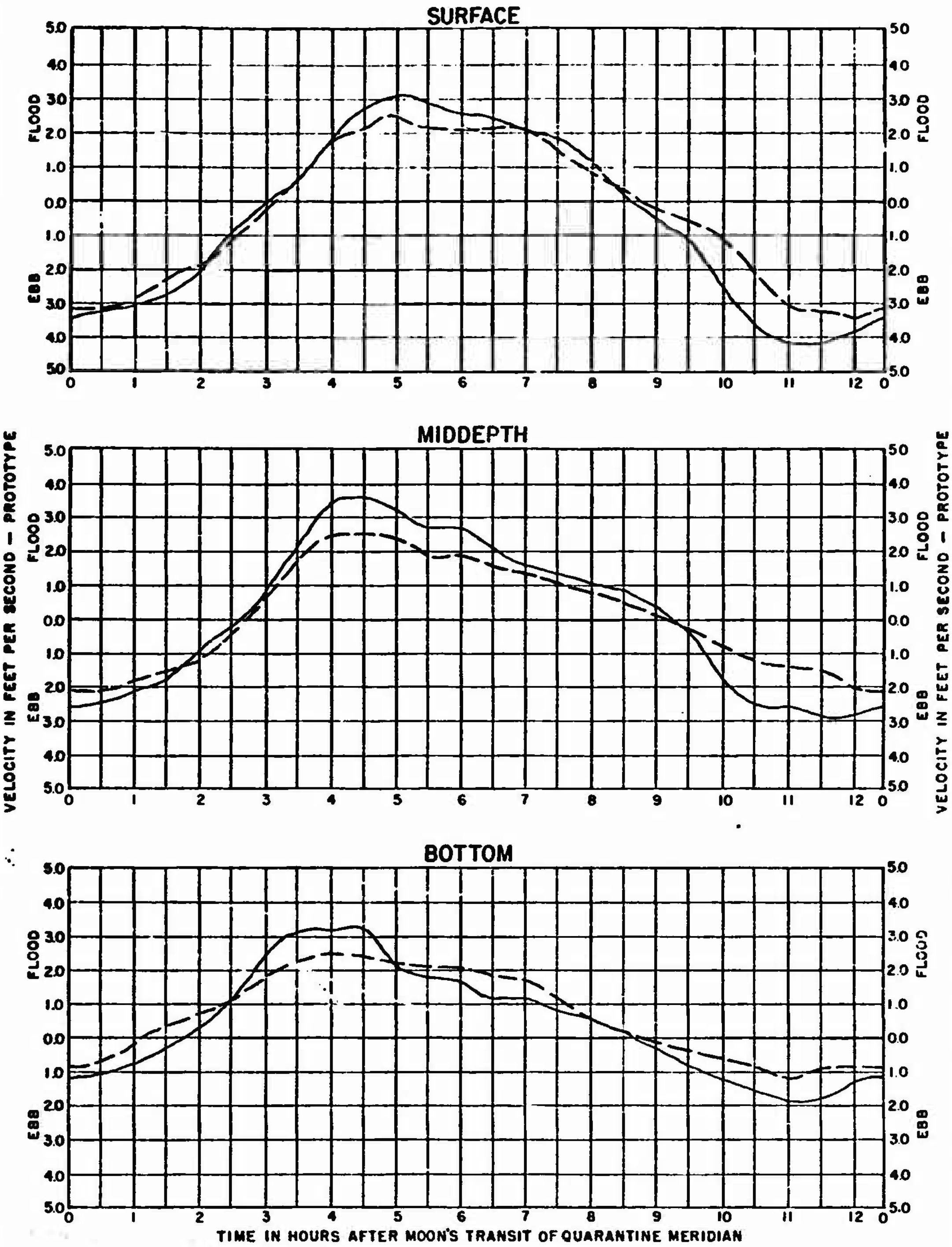
TIDE .... MEAN
FRESH-WATER DISCHARGE ... 7,000 CFS
SOURCE SALINITY .... 30,000 PPM

LEGEND

— — — — — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 153 CENTER LINE

PLATE 4



MODEL TEST DATA

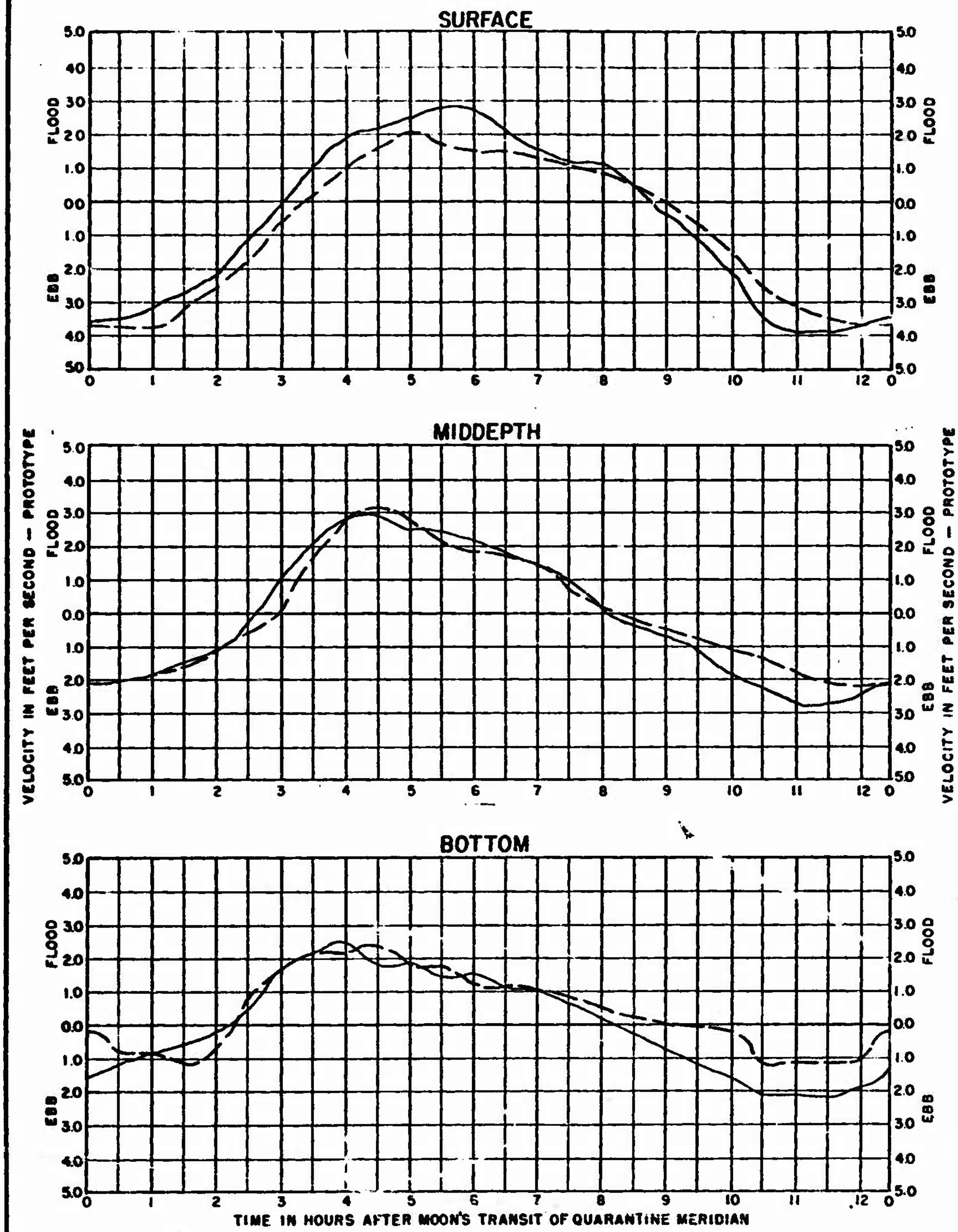
TIDE.......................... MEAN
FRESH-WATER DISCHARGE... 7,000 CFS
SOURCE SALINITY ..... 30,000 PPM

LEGEND

— — — — — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS

STATION 155 RIGHT PRISM



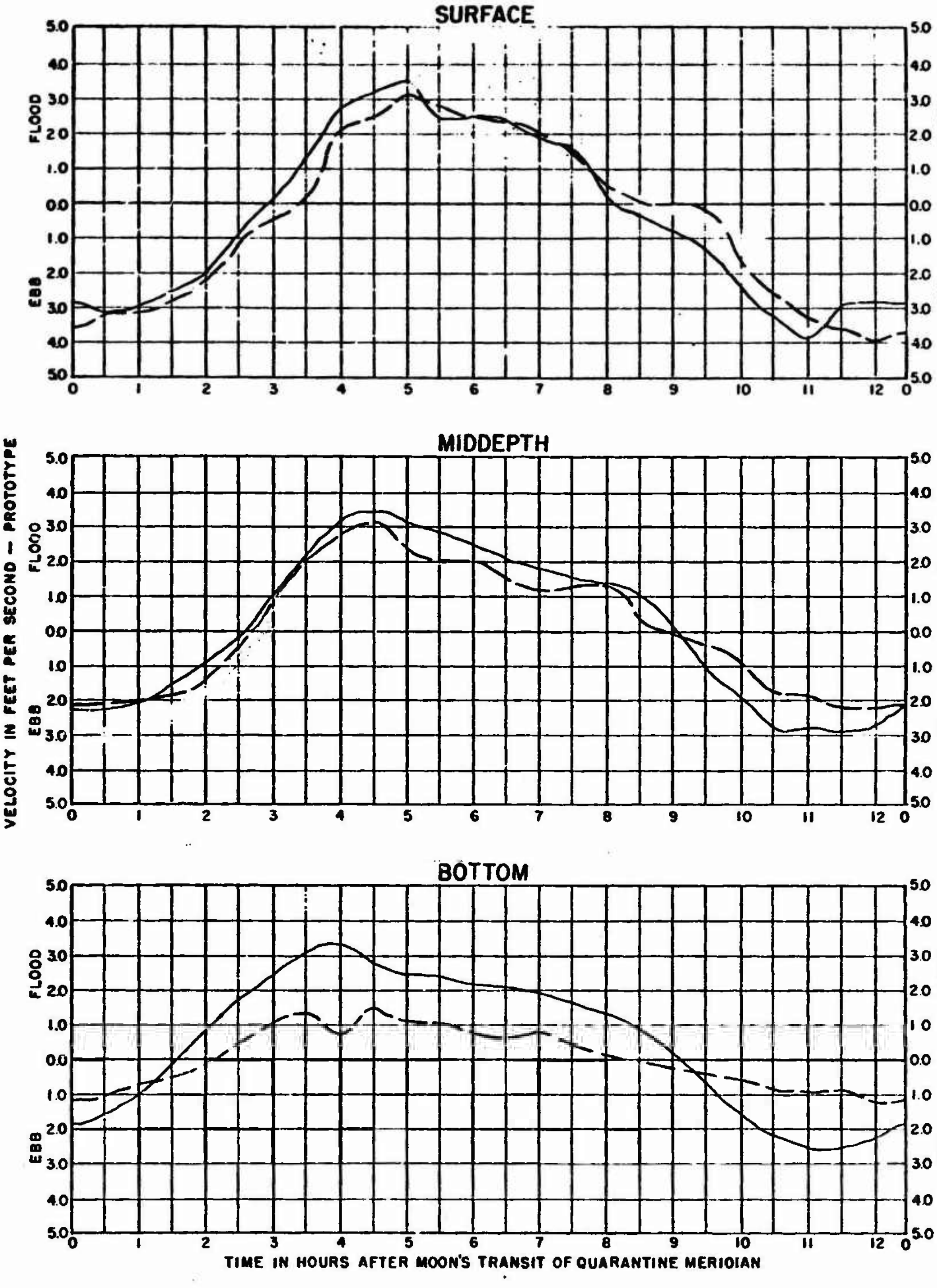
MODEL TEST DATA

TIDE .... MEAN
FRESH-WATER DISCHARGE .. 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

— — — — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 155 LEFT PRISM



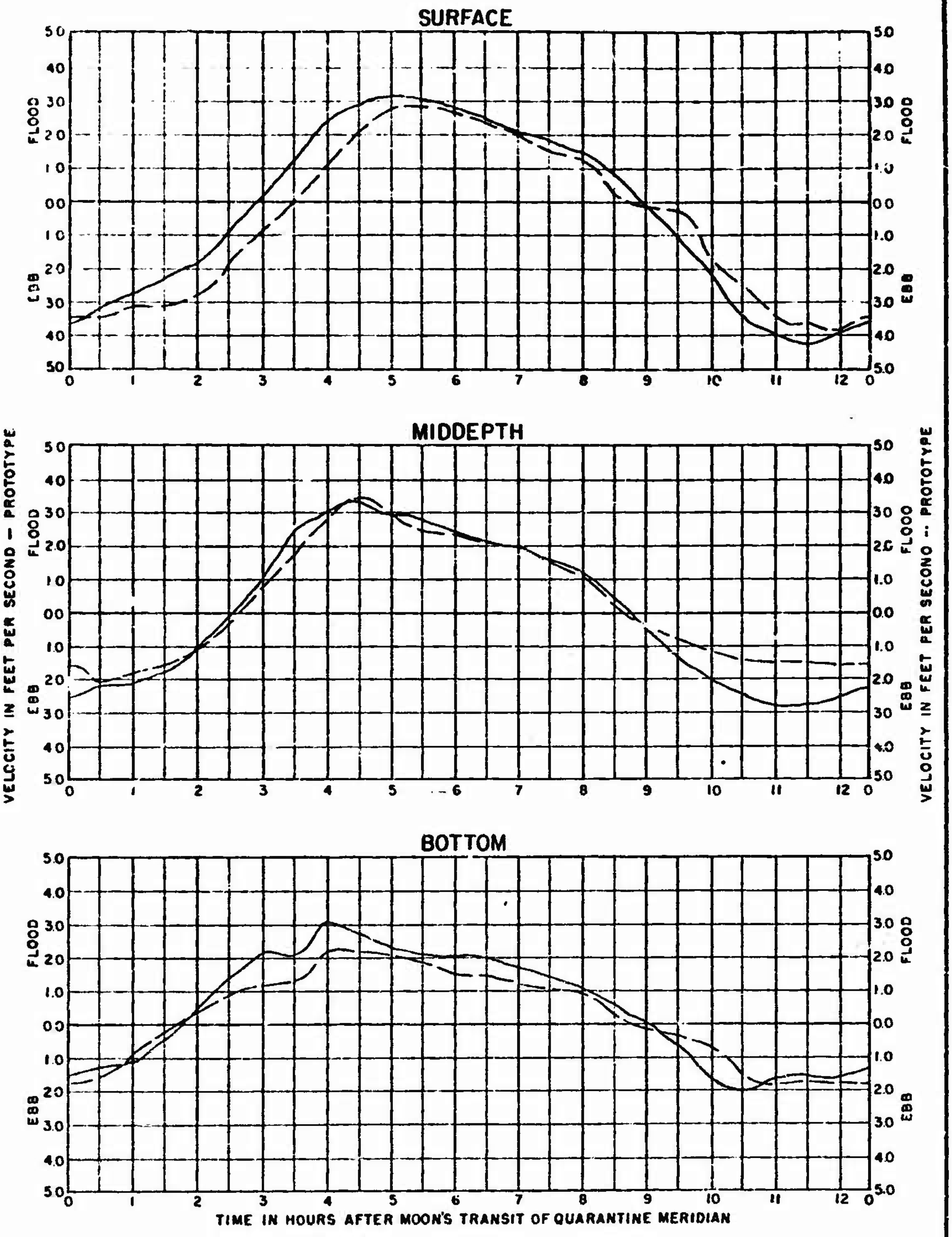
MODEL TEST DATA

TIDE .... MEAN
FRESH-WATER DISCHARGE ... 7,000 CFS
SOURCE SALINITY ..... 30,000 PPM

LEGEND

— — — — — PHASE IX, SCHEME 4, TEST 8
———— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 157 RIGHT PRISM



MODEL TEST DATA

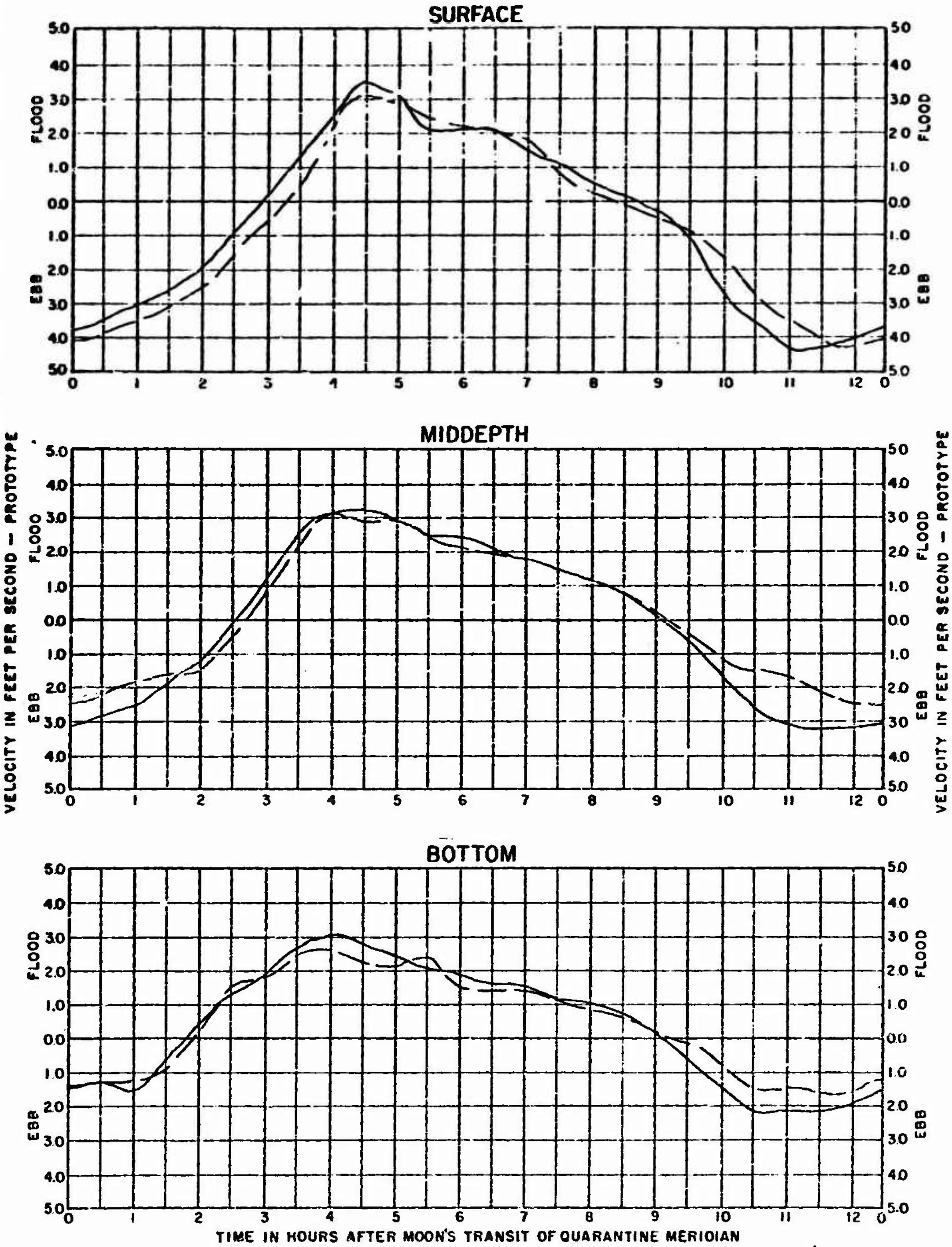
TIDE . . . . MEAN
FRESH-WATER DISCHARGE . . 7,000 CFS
SOURCE SALINITY . . . . . 30,000 PPM

LEGEND

— — — — — PHASE IX, SCHEME 4, TEST 8
———— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 157 LEFT PRISM

PLATE 8



MODEL TEST DATA

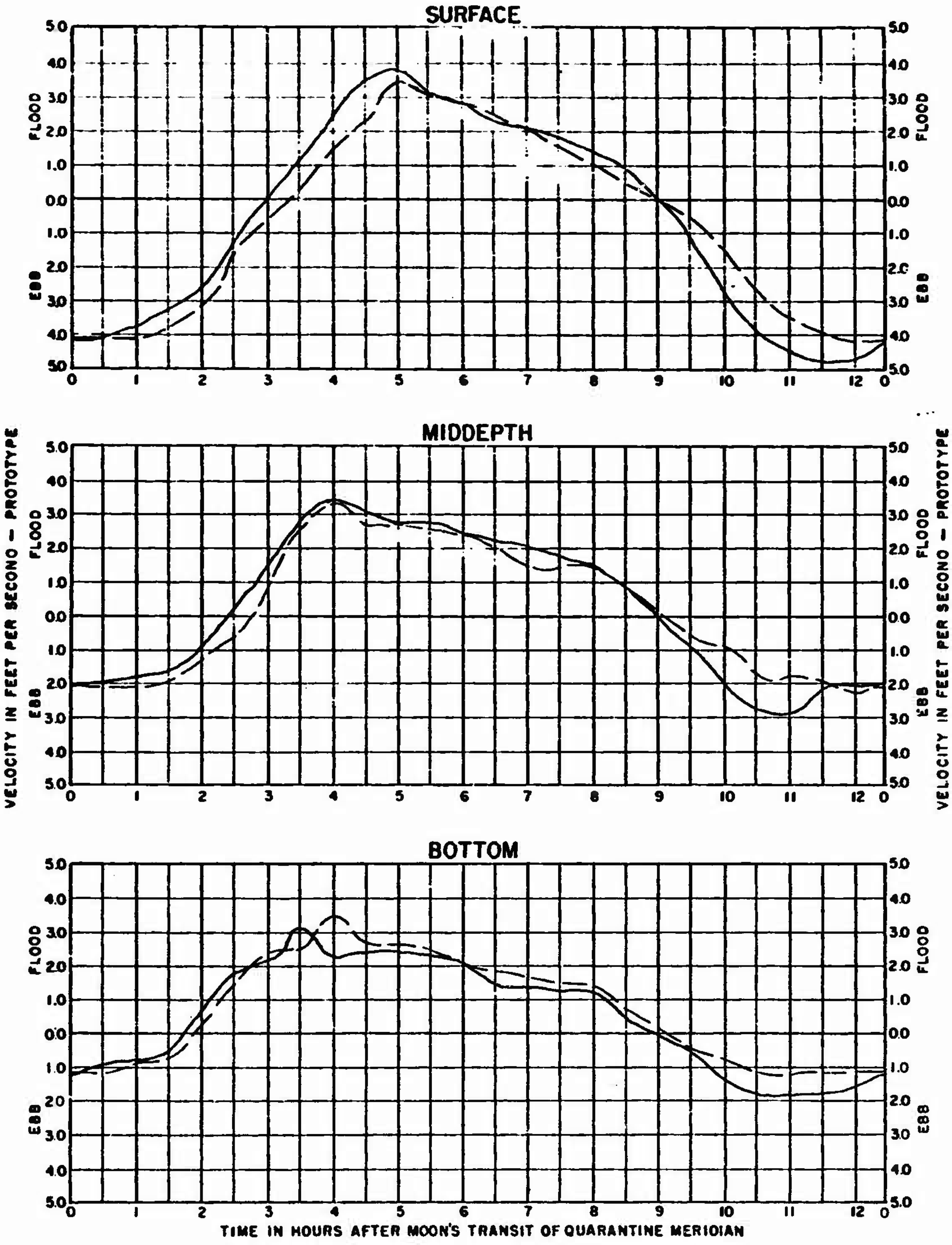
TIDE . . . . MEAN
FRESH-WATER DISCHARGE . . 7,000 CFS
SOURCE SALINITY . . . . 30,000 PPM

LEGEND

— — — — PHASE IX, SCHEME 4, TEST 8
———— 1964 CONDITIONS

VELOCITY OBSERVATIONS

STATION 159 RIGHT PRISM



MODEL TEST DATA

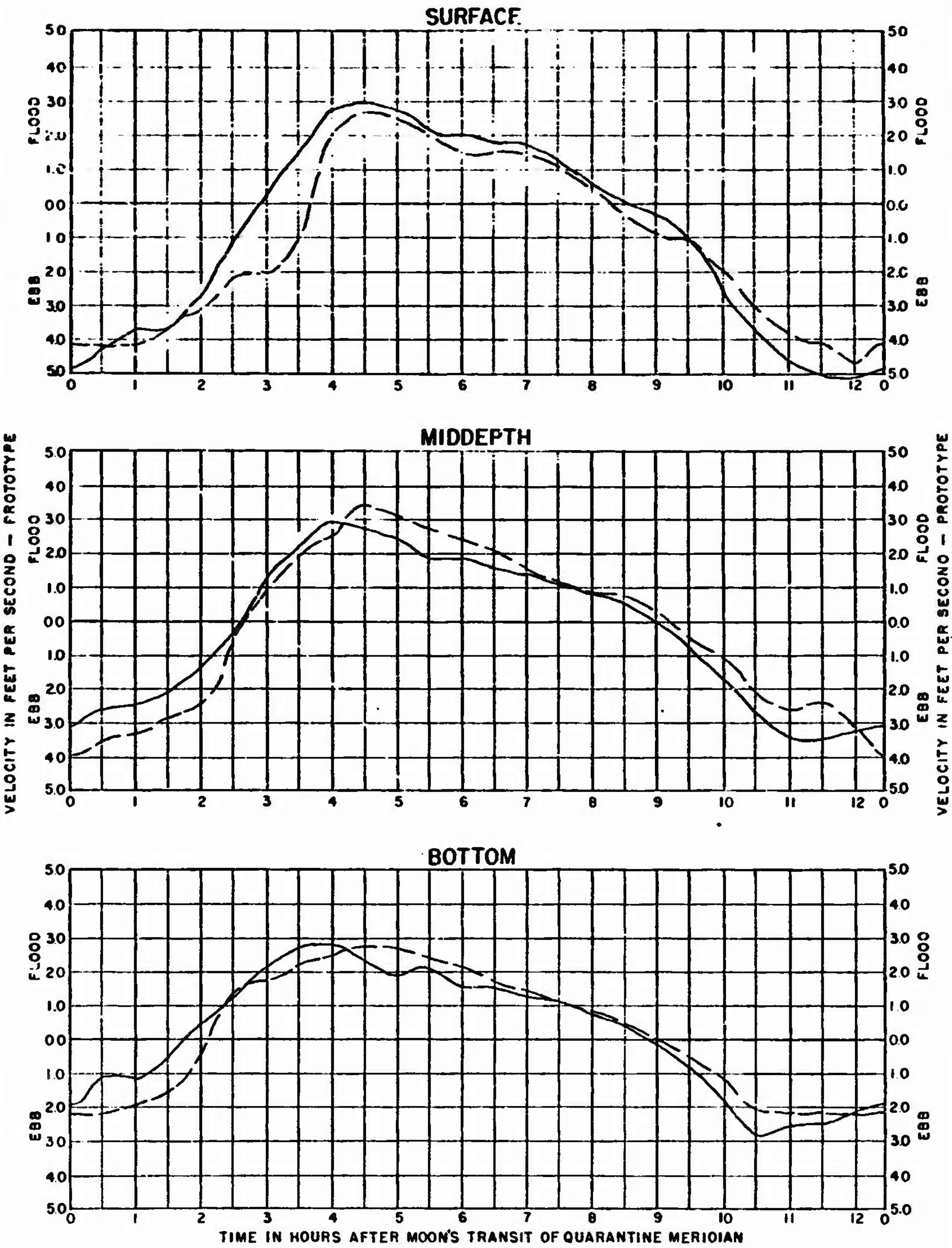
TIDE .... MEAN
FRESH-WATER DISCHARGE .. 7,000 CFS
SOURCE SALINITY .... 30,000 PPM

LEGEND

– – – – – – – PHASE II, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS

STATION 159 LEFT PRISM



MODEL TEST DATA

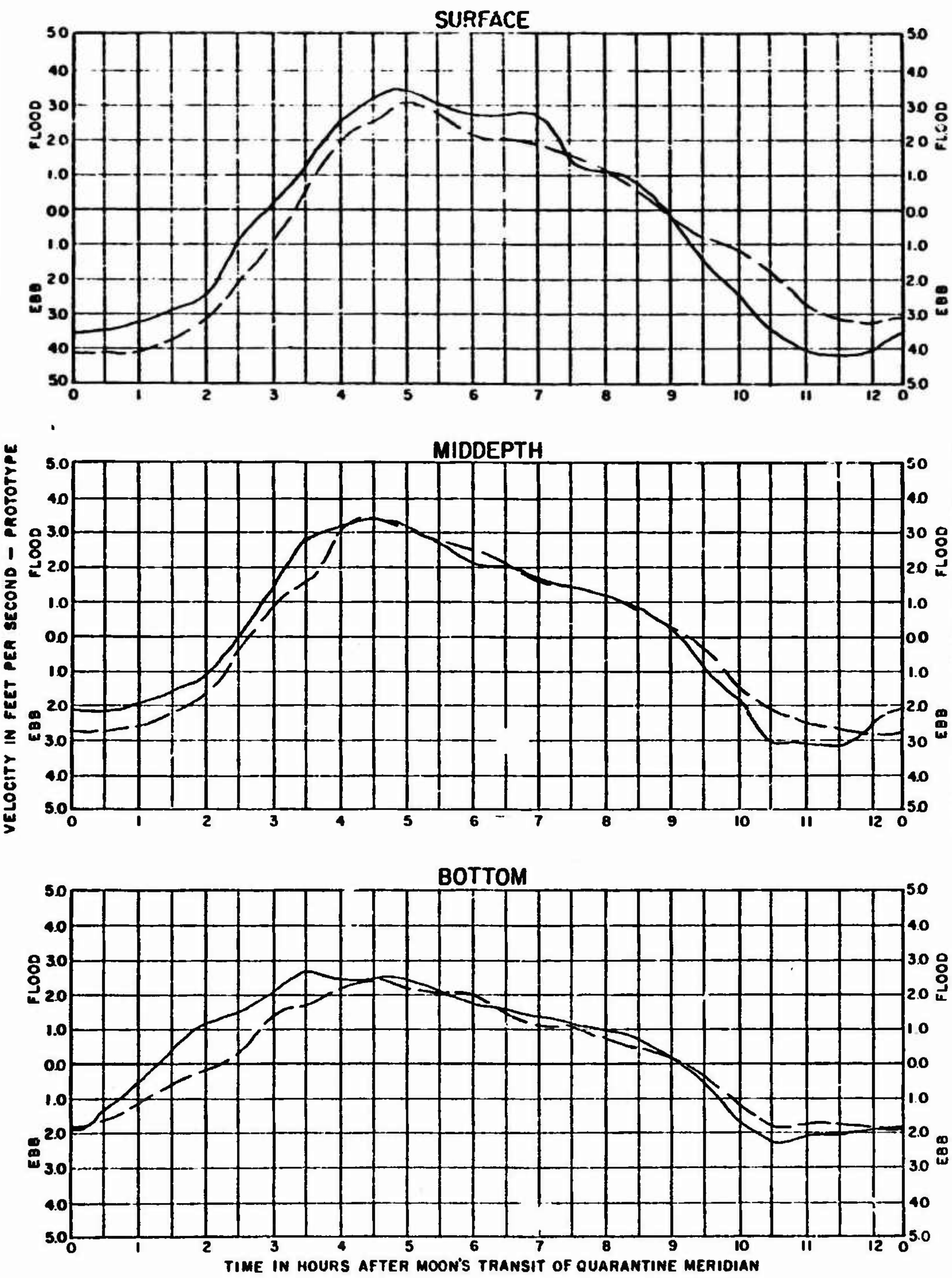
TIDE .... MEAN
FRESH-WATER DISCHARGE .. 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

———— ———— ———— ———— F IX, SCHEME 4, TEST 8
———————————— ONDITIONS

VELOCITY OBSERVATIONS

STATION 161 RIGHT PRISM



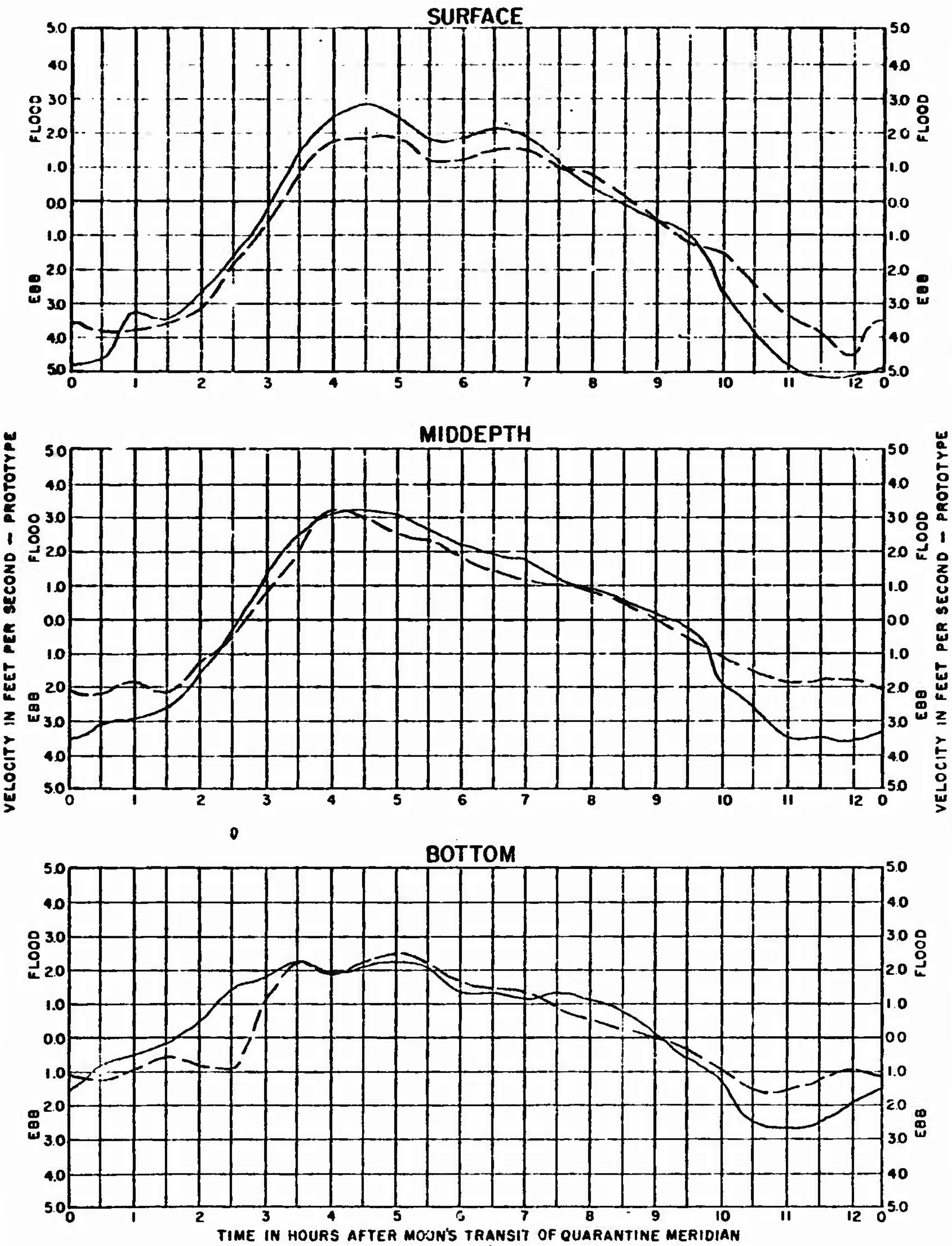
MODEL TEST DATA

TIDE .... MEAN
FRESH-WATER DISCHARGE .. 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

— — — — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 161 LEFT PRISM



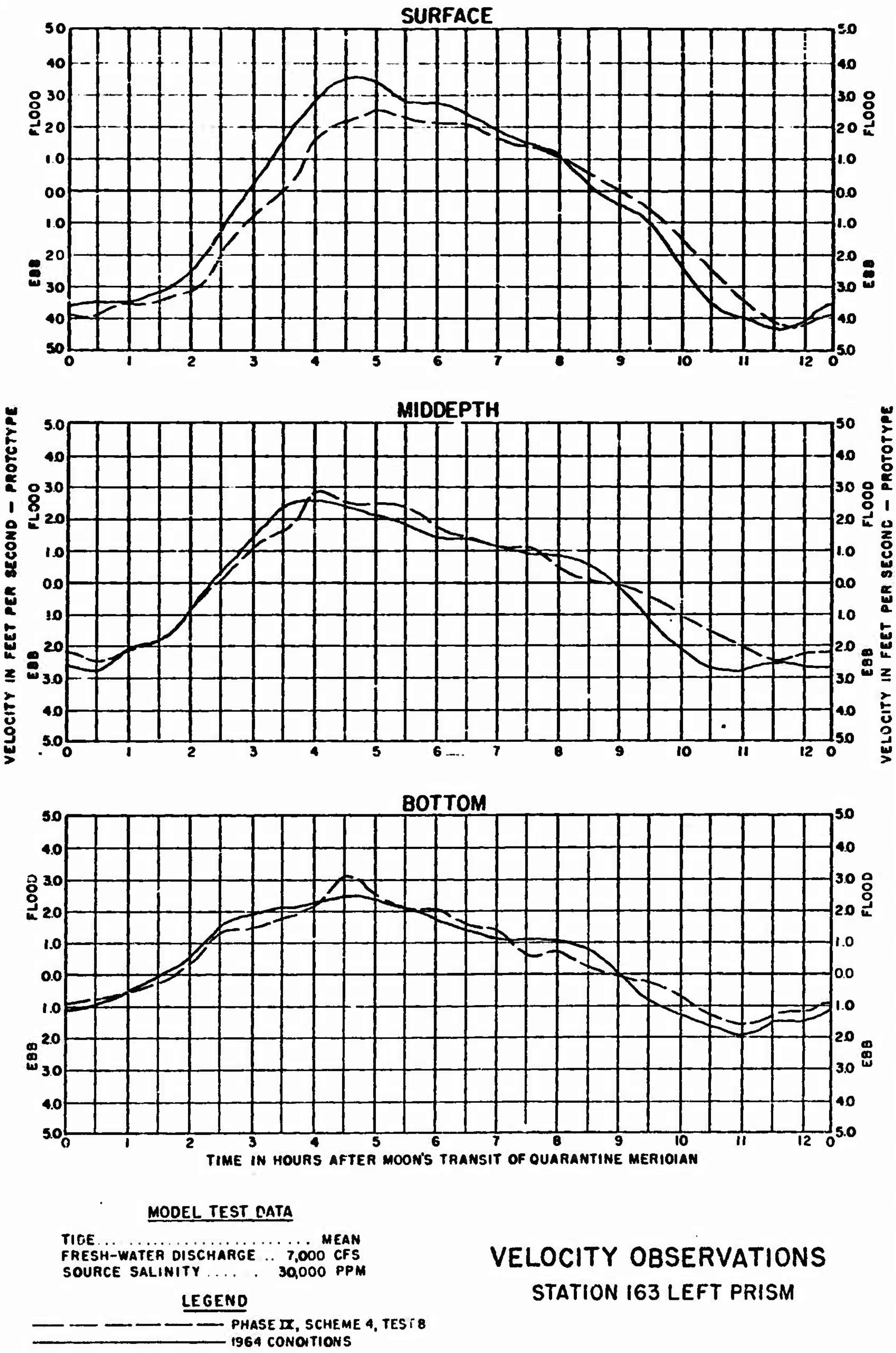
MODEL TEST DATA

TIDE . . . . MEAN
FRESH-WATER DISCHARGE . . 7,000 CFS
SOURCE SALINITY . . . . . 30,000 PPM

LEGEND

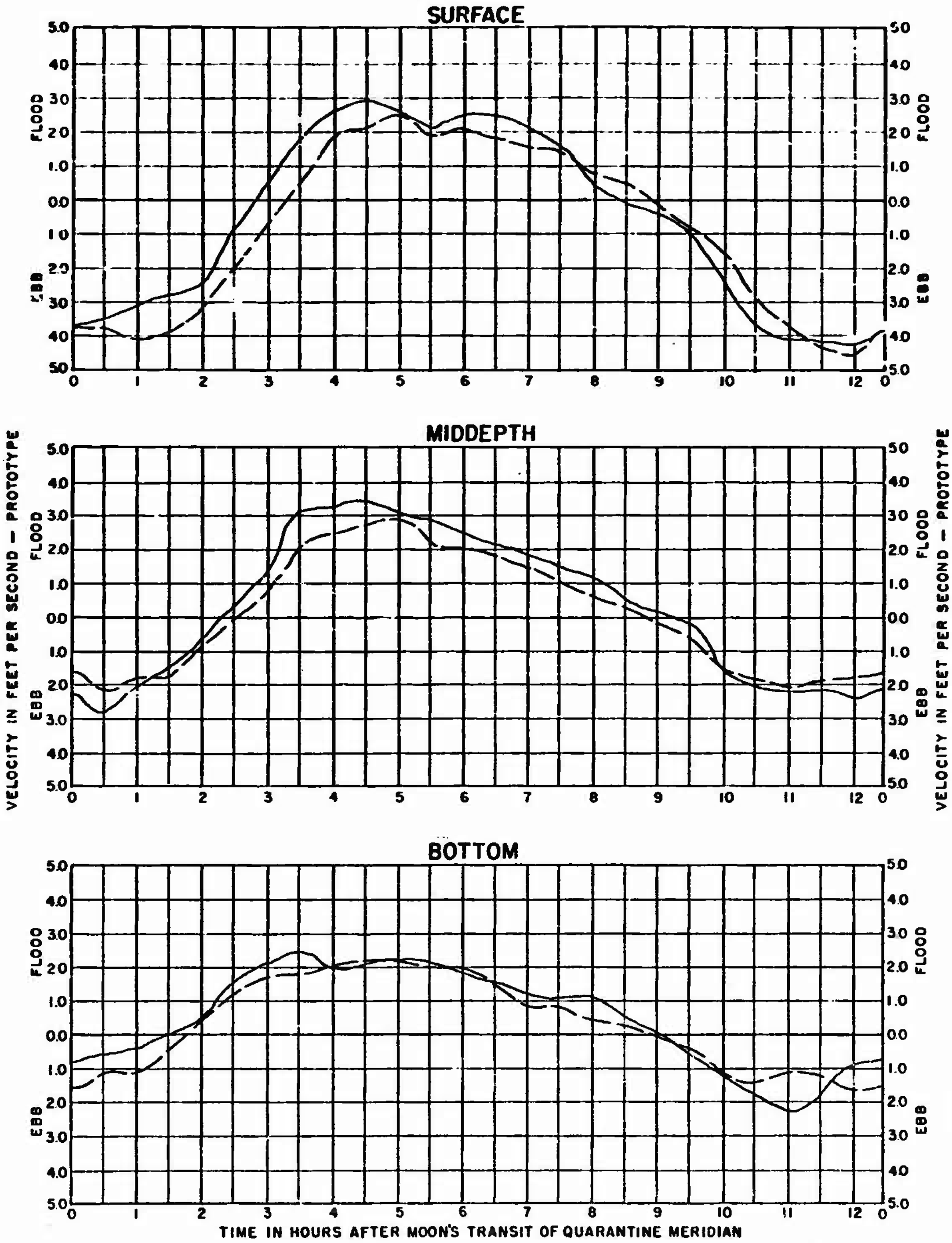
— — — — — — PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS
STATION 163 RIGHT PRISM



VELOCITY OBSERVATIONS
STATION 163 LEFT PRISM

PLATE 14



MODEL TEST DATA

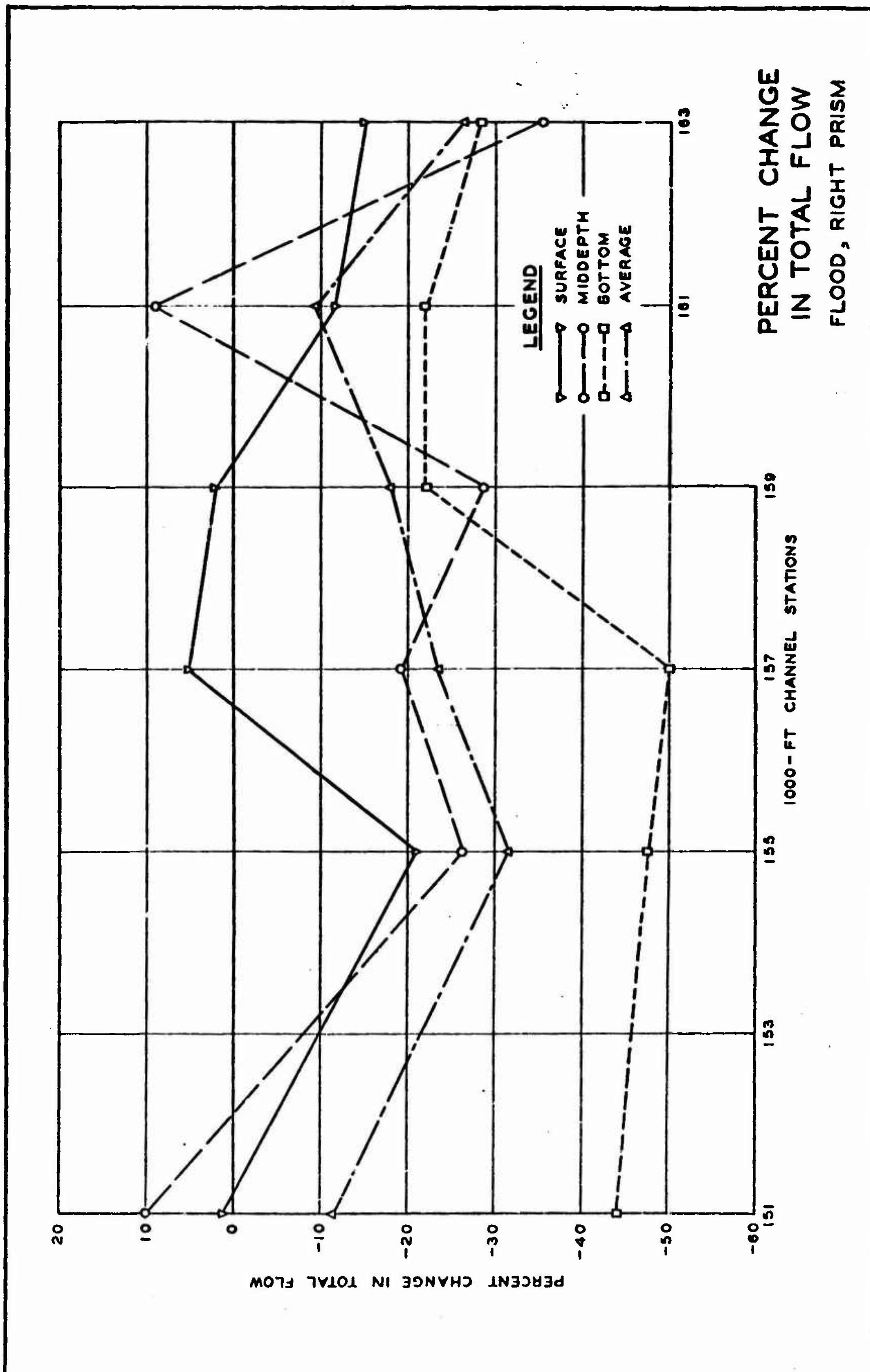
TIDE .... MEAN
FRESH-WATER DISCHARGE .. 7,000 CFS
SOURCE SALINITY .... . 30,000 PPM

LEGEND

———— ———— PHASE IX, SCHEME 4, TEST 8
———————— 1964 CONDITIONS

VELOCITY OBSERVATIONS

STATION 163 CENTER LINE



PERCENT CHANGE IN TOTAL FLOW

FLOOD, RIGHT PRISM

PLATE 16

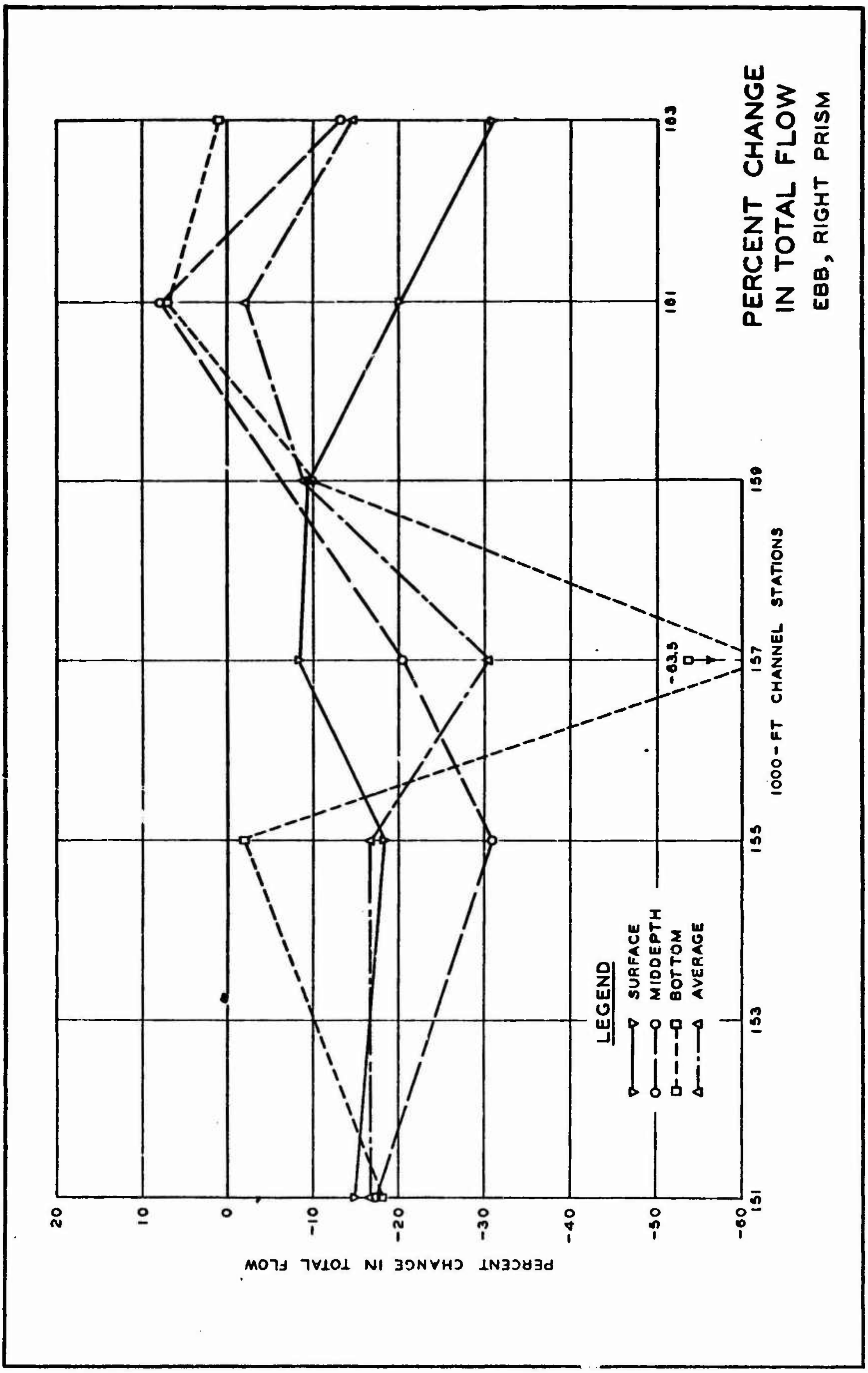

PERCENT CHANGE
IN TOTAL FLOW
EBB, RIGHT PRISM
LEGEND
SURFACE
MIDDEPTH
BOTTOM
AVERAGE
-63.5
1000-FT CHANNEL STATIONS
151
153
155
157
159
161
163
PERCENT CHANGE IN TOTAL FLOW
20
10
0
-10
-20
-30
-40
-50
-60

PLATE 17

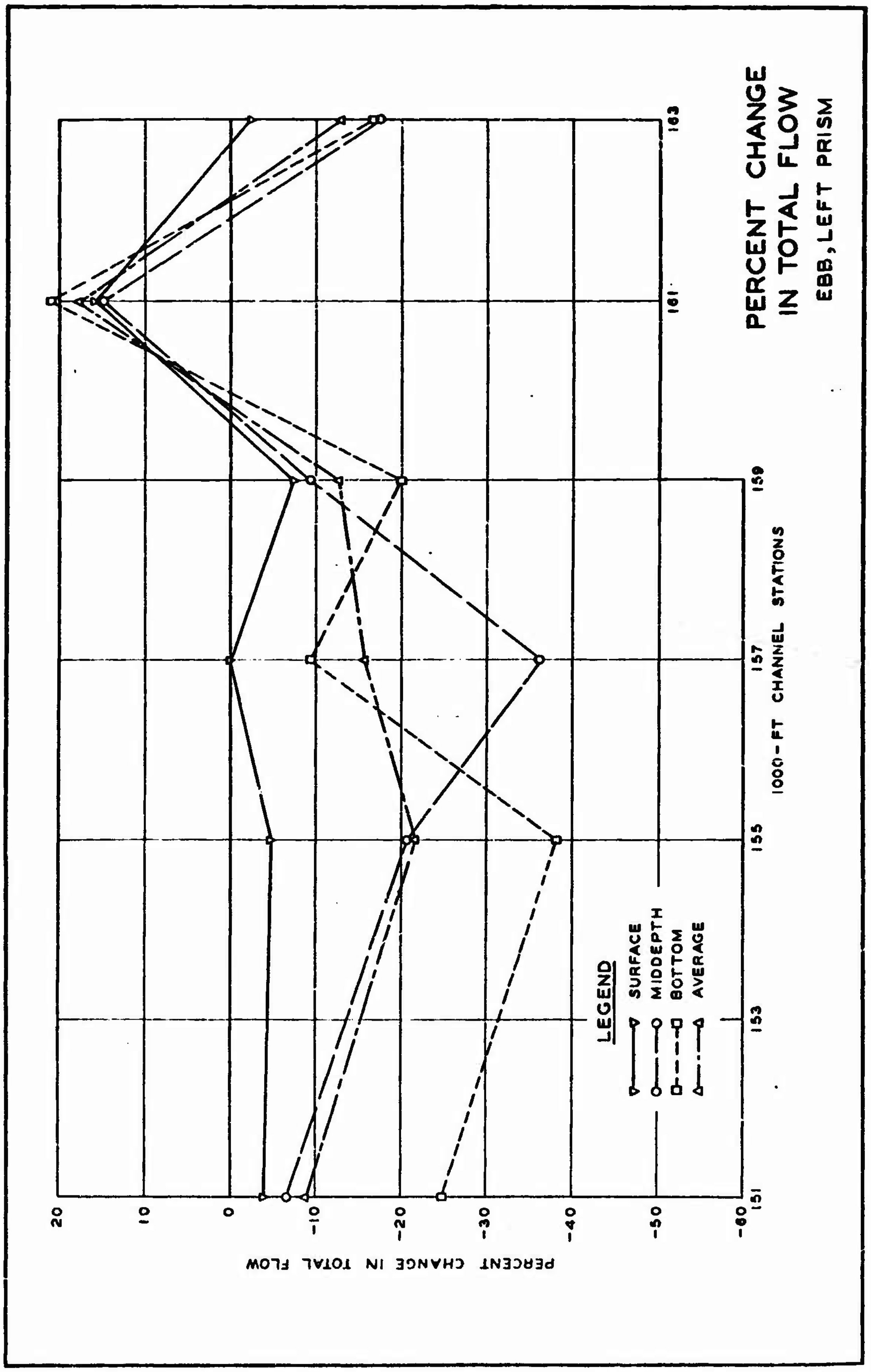
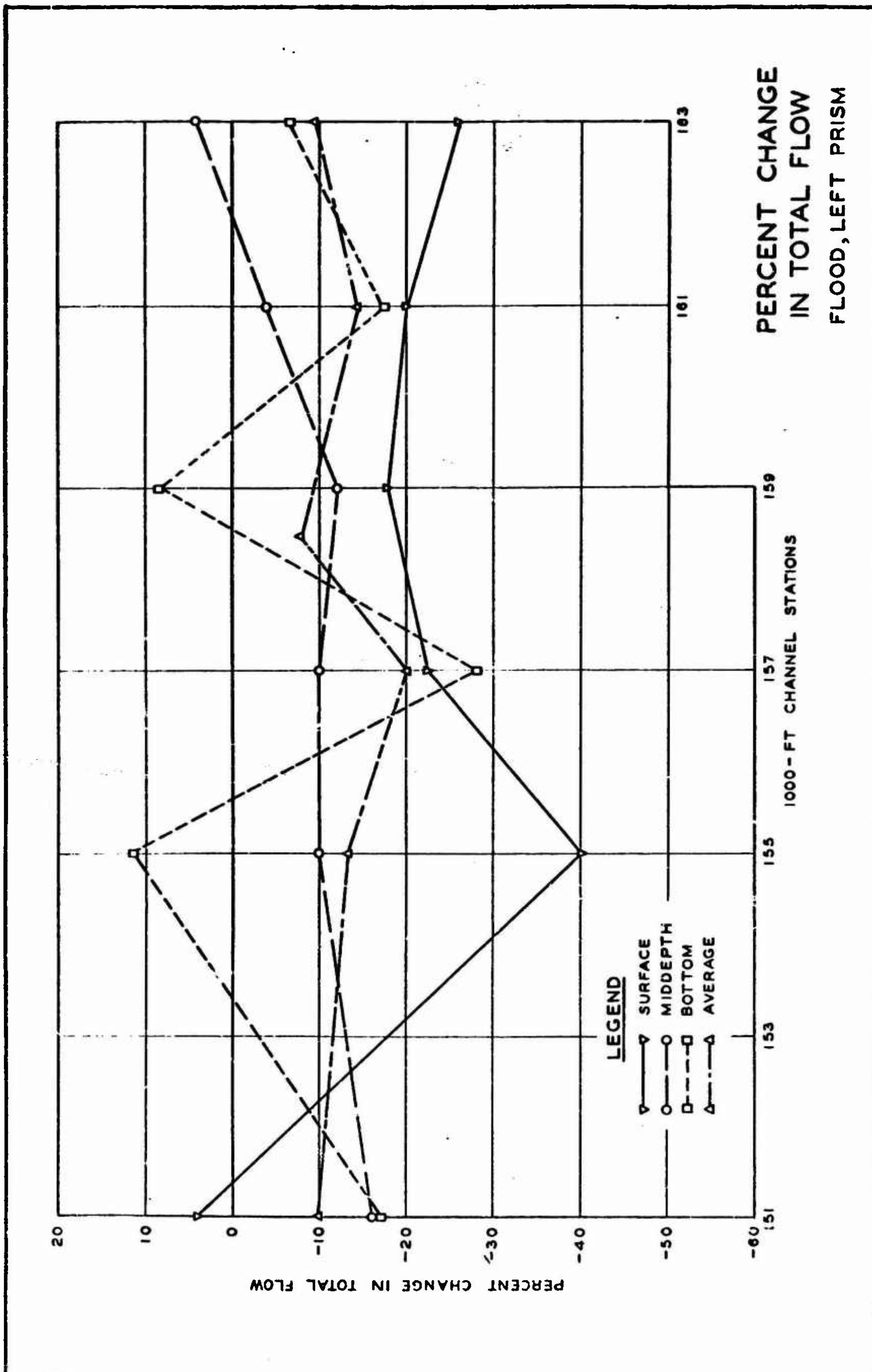

PERCENT CHANGE IN TOTAL FLOW
EBB, LEFT PRISM
LEGEND
SURFACE
MIDDEPTH
BOTTOM
AVERAGE
PERCENT CHANGE IN TOTAL FLOW
1000-FT CHANNEL STATIONS
20
10
0
-10
-20
-30
-40
-50
-60
151
153
155
157
159
161
163

PLATE 18



PERCENT CHANGE IN TOTAL FLOW

FLOOD, LEFT PRISM

PLATE 19

END